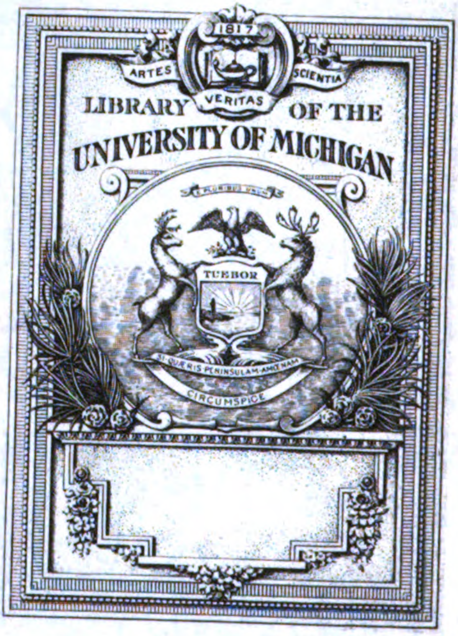
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CIRCUMSPICE

# REPORT OF THE BOARD OF MANAGERS OF THE WINCHESTE OBSERVATORY OF YALE COLLEGE TO THE PRESIDENT AND FELLOWS FOR THE ACADEMIC YEAR 1880–1881, TO WHICH IS APPENDED THE REPORT OF THE ASTRONOMER IN CHARGE OF THE HOROLOGICAL AND THERMOMETRIC BUREAUS.

REPORT OF THE BOARD OF MANAGERS OF THE WINCHESTER OBSERVATORY OF YALE COLLEGE TO THE PRESIDENT AND FELLOWS FOR THE ACADEMIC YEAR 1880–1881, TO WHICH IS APPENDED THE REPORT OF THE ASTRONOMER IN CHARGE OF THE HOROLOGICAL AND THERMOMETRIC BUREAUS.

THE BOARD OF MANAGERS OF THE WINCHESTER OBSERVATORY HEREBY REPORT TO THE PRESIDENT AND FELLOWS OF YALE COLLEGE:

During the past year Dr. Waldo has carried on with energy and success the two departments of Horology and Thermometry, which had been created previous to our report last year. We herewith present to you his report to the Board, and ask your considerate attention thereto.

The time service of the Observatory has become much more important and more valuable to the people of Connecticut by reason of the law establishing a State standard of time, and the contract entered into by the College for furnishing daily the exact time, to be transmitted by telegraph to every railway station in the State. The benefit which this contract may be confidently expected to confer upon the railway and other business interests of the State, and also upon the Observatory, is largely to be credited to the labors of Dr. Waldo.

The Thermometric Bureau is also doing excellent service for the country, and we beg your attention to Dr. Waldo's account of this branch of his work.

In the summer of 1880 a contract was completed with Messrs. Repsold, of Hamburg, for the construction of a heliometer. This instrument was to be of six inches aperture and eight feet focal length, and was to cost about $7,200, packed ready for shipment. It was expected that it would take Messrs. Repsold eighteen months to construct it. We have no reason to believe that it will not be ready for us next December.

The heliometer is an instrument hitherto unknown in the United States, and will enable us to make exact measurement rather than optical discoveries. Of large equatorials the country has a goodly number, either already in place or in process of construction. Of transit circles there are also several of the highest class. But a large and important class of problems in astronomy are open to investigation by the use of the heliometer which are not easily attacked with the ordi-

nary equipments of our observatories. It is our hope that by the use of this instrument we shall make contributions to astronomical science, not only valuable in themselves, but such as shall supplement the work of other observatories in this country. Especially we expect to make it useful in the coming transit of Venus. Observatories in New England are remarkably well situated to observe the transit, and this heliometer is as good an instrument for that occasion as it is possible to procure. The dome destined to cover the heliometer, and which is to be fifteen feet in diameter, has been already ordered of Mr. Grubb, of Dublin.

We hope to see in the near future the instruments and buildings needed for a first-class Observatory, and one worthy of the college, set up upon the north end of the Observatory lot. But our present most pressing need is the central building for offices into which all the work now in hand can be collected. That is now divided, part being done in North Sheffield Hall, part in Orange street, part in Crown street, and part in Library street. Economy in time and money demands the concentration of all the work so as to be in one place, where it may be easily done and efficiently supervised. We need the building at once. The heliometer ought not to be set up away from occupied houses lest damage come to it. It must at once on arrival next winter be mounted, so that the utmost facility in its use and full knowledge of its constants shall be gained before the time of the transit of Venus next year. It is better if possible that it be mounted in its final place on the Observatory grounds rather than suffer the considerable expense and the hazards of two mountings and of the removal.

Respectfully submitted,

C. S. LYMAN, *Pres.*
E. LOOMIS.
J. CAMPBELL.
H. A. NEWTON, *Sec'y.*

YALE COLLEGE, June 25, 1881.

At a meeting of the Board of Managers of the Winchester Observatory, held April 22, 1881, the Board put on record their sense of the loss which they have sustained in the recent death of the Hon. Oliver F. Winchester, and of his son, Mr. William W. Winchester, the former of whom by his large gifts to the department of astronomy in Yale College, and the latter by his cordial interest in forwarding his father's generous purposes have inspired the hope that the College will soon be far better supplied than ever before with the instruments and other means needed for investigation and for advanced instruction in this science.

Their practical and encouraging suggestions will be seriously missed at the meetings of the Board; but their generosity will be forever fruitful in the domain of the science which it was designed by them to promote, and it will illustrate the power which men engaged mainly in practical life have to aid in the advancement of the highest learning.

# FIRST

# ANNUAL REPORT

OF THE

# ASTRONOMER

IN CHARGE OF THE HOROLOGICAL AND THERMOMETRIC BUREAUS

OF

# THE WINCHESTER OBSERVATORY

OF

# YALE COLLEGE.

1880–1881.

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Presented to the Board of Managers at their Meeting June 3, 1881,

BY

LEONARD WALDO.

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NEW HAVEN:
TUTTLE, MOREHOUSE & TAYLOR, PRINTERS.
1881.

FIRST

# ANNUAL REPORT

1880–81.

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To the Board of Managers:

Gentlemen—This report covers the period from my appointment in November, 1879, to May 31st, 1881.

The observatory work at first contemplated was the examination of watches, marine chronometers, and clocks designed for scientific purposes, in general after the methods adopted in the foreign observatories at Liverpool and Greenwich in England, at Hamburg in Germany and at Neuchâtel and Geneva in Switzerland, and also the establishment of a public time service. Subsequently it was decided to undertake the verification of thermometers after the methods in use at the Kew Observatory of the Royal Society in England for meteorological and physiological research, and to afford facilities for the comparison of standards designed for more elaborate researches in heat.

## THE HOROLOGICAL BUREAU.

The governing Board of the Sheffield Scientific School kindly placed at our disposal the use of a room on the ground floor of North Sheffield Hall for the clocks and chronographs. With the permission of Mr. Sheffield a small but substantial brick transit house was erected a few feet from the clock room. The instruments numbered 1, 2, 3 and 7, in the following list, are placed in the transit house, while the clocks numbered 4, 5 and 6 are placed in a specially built clock-case within the room referred to. Chronograph No. 9 is placed in electric connection with these clocks and has a key for making or breaking the circuit in the transit house. The transit piers are of granite, the clock piers of brick.

North Sheffield Hall not affording the protection desirable for watch movements, arrangements were made with the

Observatory
1-25-30

INSTRUMENTAL EQUIPMENT OF THE HOROLOGICAL BUREAU.

| No. | Instrument. | Makers. | Constants. | Remarks. |
|---|---|---|---|---|
| 1 | Transit. | Troughton & Simms, London. | Aperture 3.99 in. Focal length 5.1080 ft. Edge of the cube 8.00 in. Diameter of pivots 1.465 in. Value 1 div. of the level 0''.930. Value 1 div. of the reticule 1s.495. | Provided with filar micrometer, reversing apparatus, fixed collimators and mounted on granite piers. Reticule of 25 lines by Rogers. |
| 2, 3 | Pair of collimators. | Wm. Grunow, N. Y. | Aperture 1.50 in. Focal length 17.0 in. | Reticules by Rogers. |
| 4 | Mean time standard clock. | E. Howard & Co., Boston. No. 191. | Dennison's 4-legged gravity escapement with jeweled pallets. The pendulum has a steel rod with mercurial compensation. Records the even seconds and the last 5 seconds of each minute, but omits the last 20 seconds of each 5 minutes. | An examination of the rates of this clock for a nine months trial at the Harvard College Observatory gives (Feb. to Oct. 1879) smallest mean daily rate—0s.159 (Mar.). Largest mean daily rate—0s.519 (Aug.), and the curve of rates follows the barometric curve. |
| 5 | Sideral time standard clock. | William Bond & Son, Boston. No. 367. | Bond's 6-legged gravity escapement. The pendulum has mercurial compensation and steel rod. Records each second except the 59th second of each minute. Jeweled. | Mr. Hartnup of the Liverpool and Prof. Rogers of the Harvard College Observatory have had this clock at different times. Both observers found it an unusually excellent timepiece, the latter giving its extreme variation of rate as 0s.16 for seven months in 1868. |
| 6 | Sideral clock. | Wm. Hillhouse, New Haven. | Dennison's 6-legged gravity escapement. The pendulum has a steel rod with mercurial compensation. | |
| 7 | Sideral box chronometer. | Poole, London. Resprung and adjusted by Negus. | | Eight-day chronometer. |
| 8 | Mean time pocket chronometer. | Johnson, London. No. 1436. | | |
| 9 | Chronograph. | Wm. Bond & Son, Boston. No. 313. | Bond's spring governor. Barrel 18.5 in. long and 6.0 in. diameter. Runs for $2^h.5$. | Regulated to sideral time for transit observations. |
| 10 | Chronograph. | Alvan Clark & Sons, Cambridgeport. | Clark's conical pendulum governor. Barrel 14.1 in. long and 6.0 in. diameter. Runs for $2^h.0$. | Regulated to mean time for the comparison of timepieces while rating. |
| 11, 12 | Repeating relays. | Chas. Williams, Jr., Boston. | Each 8 ohms resistance. | For repeating in three circuits simultaneously. For use with the clocks. |
| 13–25 | Telegraph sounders. | Chas. Williams, Jr., Boston. | Each 27 ohms resistance. | For use in distributing time signals on local circuits. |
| 26–35 | Thermometers. | Huddleson, Boston. | 3 maxima, 3 minima, and 3 ordinary thermometers. Fahrenheit's scale. | For use in the oven, refrigerator, and clock case. |
| 36 | Thermometer. | Kew Standard, 578. | | |
| 37 | Mercurial barometer. | James Green, N. Y. | | |
| 38, 39 | Compass galvanometers. | Chas. Wiliams, Jr., Boston. | | For detecting induced currents and tracing telegraphic interruptions. |
| 40 | Apparatus for measuring the arc of vibration of a pendulum. | Wm. Grunow, New York. | Reads, for a seconds pendulum, to 5 seconds of arc. | |
| 41 | Apparatus and closets for the testing of watch and chronometer movements. | E. Howard & Co., Boston. | Capacity of refrigerator 100 movements. Capacity of oven 100 movements. Capacity of ordinary temperature closets 800 movements. | Refrigerator provided with zinc cases containing the movements surrounded by chemically dried air. Oven heated by coils of pipe through which hot water circulates. |
| 42 | Break circuit apparatus. | E. Howard & Co., Boston. | Breaks as in clock No. 4. | Placed outside the clock and easily accessible for cleaning and repairs. |
| 43–60 | Repeating relays and sounders. | Chas. T. Chester, New York. | Each 27 ohms resistance. | |

New Haven Safe Deposit Company for space within their vaults large enough to receive the refrigerating, heating, and other closets, for the testing of watches and chronometers under their various conditions. At the rooms of the Safe Deposit Company the apparatus in the list numbered 10 and 41, with the necessary telegraphic accessories, are placed. Telegraph lines were then built and equipped connecting the Observatory rooms at North Sheffield Hall with the Safe Deposit Company, the main office of the Western Union Telegraph Company, the New Haven passenger depot of the New York, New Haven & Hartford R. R. Co., and the prominent manufacturers and jewelers of New Haven. On the organization of the Connecticut Telephone Company, permission was also granted them to construct a line, which passes through an instrument in the physical laboratory in the college yard, to connect the distributing time relay in North Sheffield Hall with their New Haven office. These various telegraph lines are the means of transmitting the Time Signals over the State at large, as described later. After this provision had been made the following observatory circular was issued, to explain the methods and conditions of the work undertaken :

*Circular of the Horological Bureau.*

This Bureau has been established by the Corporation of Yale College, at the recommendation of the Board of Managers of the Winchester Observatory, for the purpose of encouraging the higher development of the horological industries, and to pursue researches calculated to aid in the construction of refined apparatus for the measurement of Time. The Managers have also felt that the introduction of an accurate standard of Time into the community would be acceptable. They have therefore furnished to the principal Railroads and Cities of the State an accurate standard based on the meridian of the City Hall in New York, that being the nearest centre of population to which a standard time could be referred. In this work they have been assisted by the intelligent coöperation of the Railroad officers and the Board of Railroad Commissioners of the State of Connecticut. In order to gratify the (expressed) wish on the part of the makers for some proper provision for the rating of their time-pieces, the Board of Managers have made the necessary arrangements with the Safe Deposit Company of New Haven, for the erection within their steel vaults of the proper hot and cold closets, with appliances for controlling the moisture therein, and for the construction of the most recent forms of ordinary temperature closets. They have also provided for this work those appliances of modern astronomical science which can lessen the amount of personal errors, or promise to render the service more exact.

The following regulations governing the reception of time-pieces and the issue of certificates of rates, have been adopted by the Board of Managers:

## REGULATIONS GOVERNING THE ISSUE OF CERTIFICATES OF RATES OF TIME-PIECES.

### *I. Classes of Certificates.*

The following classes of certificates will be issued with time-pieces which have been deposited at this observatory for trial. The certificates will be signed by the Astronomer in charge of the Bureau, and will contain a detailed statement of the results obtained with each particular movement. In describing the positions of a movement the term "Dial up" indicates that the plane of the dial is horizontal and with the engraved side uppermost. "Dial vertical" indicates that the plane of the dial is vertical. The temperature of the refrigerator is approximately 40° F., that of the oven is approximately 90° F., and the ordinary temperature ranges between 65° and 75° F.

1. Class I. includes those certificates issued with pocket chronometers or watches which have been subjected while rating to the following variations of position and temperature:

| | |
|---|---|
| *Dial up.* | Twelve days at ordinary temperatures. |
| | One day in the refrigerator. |
| | One day in the oven. |
| *Dial vertical.* | Fourteen days pendant up. |
| | Two days pendant right. |
| | Two days pendant left. |
| *Dial down.* | Two days. |
| *Dial up.* | Eight days. |

2. Class II. includes those certificates issued with pocket chronometers or watches which have been subjected while rating to the following variations of position and temperature:

| | |
|---|---|
| *Dial up.* | One day in the refrigerator. |
| | One day in the oven. |
| | Eight days at ordinary temperatures. |
| *Dial vertical.* | Eight days pendant up. |
| | Two days pendant right. |
| | Two days pendant left. |

3. Class III. includes those certificates issued with pocket chronometers or watches which have been subjected to the following variations of position:

| | |
|---|---|
| *Dial up.* | One day in the refrigerator. |
| | One day in the oven. |
| | Eight days at ordinary temperatures. |
| *Dial vertical.* | Eight days at ordinary temperatures. |

4. Class IV., Dial vertical (pendant up), or Dial up, includes those certificates issued with pocket chronometers or watches which have been rated in the position

*Dial vertical* or *Dial up.* Twelve days at ordinary temperatures.

2

5. Class A includes those certificates issued with box chronometers (sideral or mean time) which have been rated for a minimum period of two months, and have been 24 hours in the oven and 24 hours in the refrigerator.

6. Class B includes those certificates issued with clocks which have been rated for a minimum period of three months at ordinary temperatures, and have been tested for compensation.

7. Class C includes those certificates issued with clocks which have been rated for a minimum period of six weeks at ordinary temperatures.

### *II. Conditions of Issuing Certificates.*

No certificate of the classes I., II., III., IV., A, will be issued in the following cases:

1. When the variation of rate with the dial vertical and pendant up in classes I., II., III., and in the positions indicated in classes A and IV., exceeds $2^s.0$ from one day to the following day.
2. When the variation of rate between the positions of "Dial up" and "Dial vertical" exceeds $10^s.0$.
3. When the variation for 1° F. exceeds $0^s.3$ between the ordinary temperature and the oven.
4. When the rate is greater than $10^s.0$ per day in any position.

No certificate in the classes B or C will be issued in the following cases:

5. When the variation of rate from one day to the following day exceeds $1^s.0$, except there be a barometric variation as great as 0.7 inches.
6. When the variation for 2° F. exceeds $0^s.3$.

In the cases where no certificate is issued the movement will be returned to the maker with a statement of its performance.

### *III. Cost of Certificates.*

For the purpose of enabling the Bureau to contribute to its own support as far as possible, the following charges will be made, payable on the notification that the certificates are ready to be issued in the particular cases.

| | |
|---|---|
| For Certificates of the Class I. | $5.00 |
| For Certificates of the Class II. | 3.00 |
| For Certificates of the Class III. | 2.00 |
| For Certificates of the Class IV. | 1.00 |

For classes B and C a charge will be made to cover the expense of mounting the clock upon the piers, and it will be necessary for persons desiring these certificates to confer, by letter, with the Astronomer in charge of the Bureau.

In the case of movements returned to the makers without certificates, a charge of eight cents per day will be made for rating up to the time of such return.

### *IV. Miscellaneous.*

1. All proper precautions will be taken by the Board of Managers against loss or injury by fire, theft, or otherwise. The movements will be carefully guarded under the rules which govern the Safe Deposit Company. They

will not be opened or in any way tampered with for any reason whatever; and they will not be handled, except by trained observers. If a movement should stop, it will be returned to the sender with an appropriate memorandum; but as it is manifestly inexpedient that a University Corporation should be responsible for loss or damage to property in its care for the purposes specified, it is to be understood that all risks are assumed by the persons who enter the time-pieces for certificates.

2. The Bureau will publish, in the annual report of the Astronomer in charge, the detailed rates of such time-pieces in the various classes as may seem to indicate the development of the horological art.

3. Blanks to be filled out in sending time-pieces to the Bureau will be furnished on application.

4. All movements will be wound immediately on their reception. When they have run down, however, the rating will not commence until they have been running again for five days. Unless requested otherwise, movements will be wound immediately previous to shipment from the Bureau.

5. The P. O. address of this department of the Observatory is Box 853, and time-pieces may be sent by special messenger or express directly to the safes at 89 Orange Street, New Haven, Conn. (The Adams Express Company occupy an adjoining office.)

LEONARD WALDO,

*Astronomer in charge.*

Approved and ordered to be published by the Board of Managers of the Winchester Observatory.

C. S. LYMAN, *President.* H. A. NEWTON, *Secretary.*

NEW HAVEN, CONN., June 1, 1880.

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All comparisons of pocket time-pieces are made at the same part of the second dial, and by means of the chronograph. It has been found by experiment that this means of comparing the watch movement with the observatory standard clock may be relied upon to the one-tenth of a second—a degree of accuracy exceeding that obtainable by any other known method of comparison of watches having rapid trains. The daily rates of the watches, during cloudy weather, are made to depend upon three standard clocks, all of them of a high grade of excellence and specially protected against climatic changes. Chronographic methods of registration are employed throughout in the observations for clock errors and comparisons.

As will be seen from the preceding regulations, the observatory does not receive time-pieces for the purpose of regulation, but only to examine work already finished and to give an authoritative statement of what may be expected of a particular time-piece under varying conditions. The relations between the observatory and the senders of time-pieces are confidential, except that those movements receiving certificates will be mentioned in the annual reports of the Astronomer in charge.

The following tabular view of the order and number of days in the tests to which pocket time-pieces are subjected, will be found convenient:—

| Test No. | Position and Temperature. | Class of Certificate. I. | II. | III. | IV. |
|---|---|---|---|---|---|
| 1 | Dial up, Ordinary, | 12 | | | |
| 2 | " Refrigerator, | 1 | 1 | 1 | |
| 3 | " Oven, | 1 | 1 | 1 | |
| 4 | " Ordinary, | | 8 | 8 | 12 or |
| 5 | Dial vertical, Pendant up, | 14 | 8 | 8 | 12 |
| 6 | " " right, | 2 | 2 | | |
| 7 | " " left, | 2 | 2 | | |
| 8 | Dial down, | 2 | | | |
| 9 | " up, | 8 | | | |
| | Total No. days, | 42 | 22 | 18 | 12 |

The certificates issued with any movement contain a more or less detailed statement of its performance, according to the class in which it is successful.

The following tabular view shows the class of a certificate in which any particular detail relating to a pocket time-piece may be found:—

Mean daily rate is stated in Certificates of Classes I., II., III., IV.

Mean variation is stated in Certificates of Classes I., II., III., IV.

Variation for 1° Fahr. is stated in Certificates of Classes I., II., III.

Difference before and after oven and refrigerator is stated in Certificate of Class I.

Difference between pendant up and dial up is stated in Certificates of Classes I., II., III.

Difference between pendant up and pendant right is stated in Certificates of Classes I., II.

Difference between pendant up and pendant left is stated in Certificates of Classes I., II.

Difference between dial up and dial down is stated in Certificates of Class I.

Difference between first and last week is stated in Certificates of Class I.

Difference between the extremes of rate is stated in Certificates of Classes I., II., III.

All of the records on which certificates depend are preserved at the observatory, and at any subsequent time one duplicate certificate will be issued if desired. The charges for duplicates in the various classes are as follows:—

| | | | |
|---|---|---|---|
| Class I., . . . . | $0.75 | Class III., . . . . | $0.50 |
| " II., . . . . | .60 | " IV., . . . . | .40 |

These duplicates are marked as such.

The certificates issued under the preceding regulations are not confined to watches received from dealers or makers. Any person who desires to know how a time-piece performs may enter it under the regulations, and, if it successfully passes the tests imposed, it will receive a certificate.

Where no certificate is issued, a detailed statement of its performance is returned with the movement. The statement gives the daily rate, the daily variation, the temperature at which the tests were conducted, and the various positions. It frequently serves the purpose of a certificate, especially where a certificate has not been issued on account of some slight failure in one of its requirements. Persons may, therefore, feel that whether a movement receives a certificate of one of the four classes or not it receives a careful examination, the results of which will be recorded in such a way as to be readily made use of in deciding upon its qualities.

The circular given above was sent to the leading horological journals, to as many prominent watch-makers and companies as the observatory had the address of in this country, and was published in full in the "Jeweler's Circular and Horological Review" of New York City.

In order to assign to the watches sent to us for certification a certain order of merit in this report, they have been marked upon three qualities, and that watch receiving the highest sum of marks in its class has been placed first in the accompanying tables. The three qualities and the method of computing the marks assigned were

1°. The general performance as shown by the mean daily variation of rate computed by subtracting such day's rate from the rate on the day following and dividing the numerical sum of these daily variations by the number of days, but omitting the daily variations when a change of position occurred. The mark for a mean daily variation exceeding $2^s.0$ is taken as 0, and the mark for a watch having no variation would be the greatest possible. We have assumed the general performance to be equal in value to the adjustment for position, and we assume the maximum mark to be 40.

The mark for any particular watch may be computed by the formula

$$\frac{2^s.00\text{—the mean daily variation}}{0.05}=\text{the mark for daily variation.}$$

2°. The adjustment for position, as shown by the mean of the deviations of the rates in different positions from the mean rate during the whole trial. With the assumption that this is of equal importance to (1) we have assumed the maximum mark to be 40.

The mark to be assigned to any watch has been computed from the formula

$$\frac{10^s\text{—mean position variation}}{0^s.25}=\text{the mark for position variation.}$$

This is based upon the consideration that the greatest rate in any position cannot exceed 10 seconds.*

3°. The adjustment for compensation in temperature has been assumed to be of half the value of the adjustments necessary for a maximum mark in 1° and 2°, and therefore receives the maximum of 20. The mark to be assigned to any watch for this adjustment has been computed from the formula

$$\frac{0^s.30\text{—variation for } 1^\circ \text{ Far.}}{0^s.015}=\text{the mark for temperature compensation.}$$

This is based upon the consideration that the max m limit of temperature variation is fixed at $0^s.30$ for $1^\circ$ Fa r.

In the following tables, I, II, III, are given the results of the rating of watches which received certificates of the classes I, II, III during the year. Class IV, which comprised 33 watch certificates, has not been given. The test was in but one position, and the tables given sufficiently indicate the work of the Bureau. The last four columns give the numbers computed for the relative rank of the watch as compared with the others sent in to the observatory and which received certificates of the same class.

* To illustrate the method adopted in assigning the marks given for the adjustment in position, the computation for the first watch in Table I. is here given:

| | | | |
|---|---|---|---|
| Let p = | the rate, pendant up, which we can assume to be | = | $0^s.00$ |
| d = | " " dial " which, for p = $0^s.00$, | = | + 1.32 |
| r = | " " pendant right, " " " | = | − 2.57 |
| l = | " " " left, " " " | = | − 1.67 |
| D = | " " dial down, " " " | = | − 0.22 |

$$\text{Let } M = \frac{p+d+r+l+D}{5} = \frac{-3^s.14}{5} = 0^s.63$$

The mean position variation will then be:

$$\frac{(m \sim p)+(m \sim d)+(m \sim r)+(m \sim l)+(m \sim D)}{5} = \frac{5.97}{5} = 1.19$$

where all the differences have the positive sign.

Now applying the formula in 2° we have:

$$\frac{10.00 - 1.19}{0.25} = 35.2$$ for the mark assigned, of which we reject the decimal two tenths and obtain the 35 given in column 17, Table I.

The other columns are so readily computed from the formulæ that they need no explanation.

## TABLE No. I.—WATCH MOVEMENTS OBSERVED FOR 42 DAYS, IN FIVE POSITIONS, AND IN THE OVEN, AND REFRIGERATOR, AND WHICH RECEIVED CLASS I. CERTIFICATES.

| Rank. | Maker's Number. | Name engraved on the face of the Watch. | Escapement. | Spring. | Mean daily rate. | Mean daily variation. | Variation for 1° Fah. | Diff. before and after oven and refrigerator | Diff. bet. pedant up and dial up. | Diff. Pend. up & Pend't right. | Diff. Pend't up & Pend't left. | Diff. Dial up and Dial down. | Diff. first and last weeks. | Diff. bet. extremes of rate. | Mark computed for Daily variation | Mark computed for Position. | Mark computed for Temperature. | Mark computed for Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | | | | | s. | s. | s. | s. | s. | s. | s. | s. | s. | s. | | | | |
| 1 | 999933 | American Watch Co.,-- | Straight line Lever, | Breguet,---- | +2.60 | 0.45 | −0.04 | +0.40 | −1.32 | +2.57 | +1.67 | +1.54 | −0.01 | 5.5 | 31 | 35 | 17 | 83 |
| 2 | 871143 | American Watch Co.,-- | " " " | " ---- | −1.62 | 0.65 | +0.01 | +2.13 | +6.52 | +3.32 | +3.07 | −2.25 | +1.40 | 10.0 | 27 | 34 | 19 | 80 |
| 3 | 999931 | American Watch Co.,-- | " " " | " ---- | +0.75 | 0.69 | +0.03 | −0.53 | −3.22 | +0.47 | +2.37 | +1.69 | +1.61 | 7.9 | 26 | 34 | 18 | 79 |
| 4 | 14982 | Mathez Watch Co., ---- | ---------------- | Breguet,---- | −2.21 | 0.46 | +0.13 | +0.77 | +0.04 | +1.29 | +2.79 | +0.70 | +1.70 | 8.1 | 31 | 36 | 11 | 78 |
| 5 | 999920 | American Watch Co.,-- | Straight line Lever, | " ---- | +4.29 | 0.67 | +0.04 | −0.30 | +1.86 | +6.28 | +2.93 | +2.12 | −1.07 | 7.9 | 27 | 33 | 17 | 77 |
| 6 | 4403 | Patek, Philippe & Co., | Lever,------------ | ------------ | −2.24 | 0.37 | +0.06 | −0.93 | −5.42 | +3.71 | +2.31 | +0.80 | −2.56 | 10.5 | 33 | 27 | 16 | 76 |
| 7 | 999928 | American Watch Co.,-- | Straight line Lever, | Breguet,---- | +0.31 | 0.79 | −0.08 | +0.47 | −0.31 | −0.36 | +2.74 | +0.55 | −1.70 | 5.8 | 24 | 37 | 15 | 76 |
| 8 | 50186 | Patek, Philippe & Co., | Lever,------------ | ------------ | −0.08 | 0.55 | +0.02 | +0.20 | −10.17 | −4.29 | −8.19 | +2.63 | −0.23 | 12.2 | 29 | 27 | 19 | 75 |
| 9 | 44249 | Nicoud & Howard, ---- | Anchor, ---------- | " ---- | −4.63 | 0.65 | +0.11 | −1.08 | −0.06 | −0.64 | +3.66 | −2.78 | −2.43 | 7.7 | 27 | 34 | 13 | 74 |
| 10 | 999972 | American Watch Co.,-- | " " " | " ---- | +2.65 | 0.65 | +0.01 | +0.30 | −2.30 | +6.26 | +6.01 | +10.31 | −3.38 | 13.0 | 27 | 25 | 19 | 71 |
| 11 | 12091 | Paul Breton,---------- | " " " | " ---- | +0.44 | 0.80 | +0.07 | −3.3 | +0.91 | +5.59 | −4.16 | −3.12 | +0.18 | 15.3 | 24 | 30 | 15 | 69 |
| 12 | 14979 | Mathez Watch Co., ---- | ---------------- | Breguet,---- | −6.49 | 0.90 | +0.13 | −0.37 | +1.90 | −0.49 | −0.49 | +4.34 | −0.17 | 9.1 | 22 | 36 | 11 | 69 |
| 13 | 42582 | Frederic Nicoud,------ | Anchor, ---------- | Breguet,---- | +4.09 | 1.01 | −0.02 | −0.20 | −0.45 | −5.23 | +4.67 | −2.55 | −4.31 | 10.6 | 20 | 30 | 19 | 69 |
| 14 | 14984 | Mathez Watch Co.,---- | ---------------- | ------------ | −5.28 | 0.86 | −0.08 | +1.55 | −3.45 | +0.36 | −4.16 | +7.56 | +2.09 | 10.2 | 23 | 30 | 15 | 68 |
| 15 | 34632 | Patek, Philippe & Co., | Lever,------------ | ------------ | −2.68 | 0.69 | +0.17 | −0.88 | +0.69 | +6.65 | +1.30 | +0.31 | −1.08 | 11.5 | 26 | 32 | 9 | 67 |
| 16 | 733 | Parkinson & Frodsham, | ---------------- | ------------ | +3.15 | 0.85 | −0.06 | −0.12 | −1.40 | +8.01 | −1.99 | +0.06 | +0.13 | 13.3 | 23 | 28 | 16 | 67 |
| 17 | 871188 | American Watch Co.,-- | " " " | " ---- | +0.78 | 0.74 | −0.04 | +0.63 | −3.47 | +7.24 | +7.39 | −3.76 | −1.36 | 13.0 | 25 | 24 | 17 | 66 |
| 18 | 44230 | Bailey, Banks & Biddle, | Anchor, ---------- | Breguet,---- | −1.41 | 1.09 | −0.06 | +0.72 | −4.65 | +0.96 | −7.84 | −1.69 | +0.96 | 11.7 | 18 | 28 | 16 | 62 |
| 19 | 24792 | Patek, Philippe & Co., | Lever,------------ | ------------ | +2.94 | 1.33 | +0.11 | +1.73 | +0.54 | −1.76 | −7.06 | −2.10 | +2.90 | 13.8 | 13 | 32 | 17 | 58 |
| 20 | 44232 | Bailey, Banks & Biddle, | Anchor, ---------- | " ---- | −4.74 | 0.99 | −0.09 | +[illegible].60 | −6.72 | −16.55 | −8.15 | +5.76 | +0.59 | 13.4 | 20 | 21 | 14 | 55 |
| 21 | 43247 | Frederic Nicoud,------ | Anchor, ---------- | Vert. Spiral. | −4.59 | 1.85 | −0.09 | −1.[illegible] | −5.88 | +0.57 | +0.87 | +5.10 | +1.96 | 16.7 | 3 | 32 | 14 | 49 |
| 22 | 45469 | E. Howard & Co., ----- | Lever,------------ | ------------ | +0.57 | 1.07 | +0.32 | −0.9[illegible] | −2.33 | −0.14 | +7.26 | −4.28 | −2.18 | 14.8 | 19 | 27 | 0 | 46 |

The sign + indicates
- in column 6, that the watch gains time.
- " 8, " gaining rate of the watch increases as the temperature increases.
- " 9, " " " " " after being tested in oven and refrigerator.
- " 10, 11, 12, 13, that the watch gains in the first of the two positions compared.
- " 14, " " " the last week.

Nos 9, 15 and 19 were deposited by private persons owning the respective movements.

TABLE No. II.—WATCH MOVEMENTS OBSERVED FOR THREE WEEKS, IN FOUR POSITIONS, AND IN OVEN AND REFRIGERATOR, AND WHICH RECEIVED CLASS II. CERTIFICATES.

| Rank. | Maker's Numbers. | Maker's Name. | Escapement. | Spring. | Mean daily rate. | Mean daily variation. | Variation for 1° Fahr. | Diff. bet. Pendant up and Dial up. | Diff. bet. Pendant up and Pendant r'gt. | Diff. bet. Pendant up and Pendant left. | Diff. bet. extremes of rate. | Mark computed for Daily variat'n | Temper-ature. | Position. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | | | | | s. | s. | s. | s. | s. | s. | s. | | | | |
| 1 | 1056252 | American Watch Co. | Straight line lever. | Flat. | —1.98 | 0.48 | — 0.01 | —2.75 | —1.74 | —0.49 | 3.9 | 30 | 20 | 36 | 86 |
| 2 | 1140585 | " " " | " " " | " | —0.88 | 0.48 | —0.06 | +0.16 | —2.52 | —1.83 | 7.1 | 30 | 16 | 35 | 81 |
| 3 | 1056227 | " " " | " " " | " | +0.32 | 0.49 | —0.05 | +0.31 | —3.30 | —2.50 | 6.4 | 30 | 17 | 34 | 81 |
| 4 | 1056240 | " " " | " " " | " | —3.77 | 0.56 | +0.03 | —6.25 | —3.41 | —3.41 | 7.8 | 29 | 18 | 33 | 80 |
| 5 | 1056244 | " " " | " " " | " | —0.93 | 0.65 | —0.04 | +0.25 | +0.61 | —2.14 | 3.1 | 27 | 17 | 36 | 80 |
| 6 | 1056253 | " " " | " " " | " | +0.02 | 0.36 | —0.15 | +0.78 | +1.26 | —1.94 | 8.4 | 33 | 10 | 36 | 79 |
| 7 | 1056243 | " " " | " " " | " | +1.77 | 0.38 | —0.13 | —1.13 | —3.87 | —0.77 | .62 | 32 | 11 | 35 | 78 |
| 8 | 1056245 | " " " | " " " | " | —0.16 | 0.48 | +0.02 | —4.63 | —7.40 | —7.95 | 9.2 | 30 | 19 | 29 | 78 |
| 9 | 1056239 | " " " | " " " | " | —0.15 | 0.41 | +0.07 | —3.83 | —8.24 | —5.94 | 9.2 | 32 | 15 | 30 | 77 |
| 10 | 1140511 | " " " | " " " | " | —0.20 | 0.52 | —0.05 | —1.67 | —6.11 | +1.14 | 8.0 | 30 | 17 | 30 | 77 |
| 11 | 1056241 | " " " | " " " | " | —6.46 | 0.34 | +0.07 | +5.65 | +8.08 | +9.32 | 9.7 | 33 | 15 | 28 | 76 |
| 12 | 1056238 | " " " | " " " | " | —1.43 | 0.41 | —0.07 | —4.13 | —5.28 | +1.97 | 7.9 | 32 | 15 | 29 | 76 |
| 13 | 1140588 | " " " | " " " | " | +3.58 | 0.41 | +0.11 | +3.98 | —3.23 | —2.03 | 10.0 | 32 | 13 | 31 | 76 |
| 14 | 1056216 | " " " | " " " | " | +5.83 | 0.36 | —0.12 | +3.24 | +0.88 | +8.27 | 8.5 | 33 | 12 | 30 | 75 |
| 15 | 1152437 | " " " | " " " | " | +0.76 | 0.62 | —0.07 | +1.3 | —2.5 | +4.2 | 9.4 | 28 | 15 | 32 | 75 |
| 16 | 1056231 | " " " | " " " | " | +0.43 | 0.99 | 0.00 | —0.93 | —0.24 | +3.11 | 5.5 | 20 | 20 | 35 | 75 |
| 17 | 1140579 | " " " | " " " | " | —3.76 | 0.61 | +0.09 | —0.86 | +2.94 | +3.68 | 6.7 | 28 | 14 | 32 | 74 |
| 18 | 1140581 | " " " | " " " | " | —0.42 | 0.49 | +0.14 | —0.69 | —3.55 | —4.65 | 8.7 | 30 | 11 | 32 | 73 |
| 19 | 1056234 | " " " | " " " | " | +2.40 | 0.63 | —0.16 | +1.34 | —1.72 | —0.47 | 7.9 | 27 | 9 | 36 | 72 |
| 20 | 1056247 | " " " | " " " | " | +1.41 | 1.06 | —0.01 | +3.65 | —0.08 | —0.17 | 7.9 | 19 | 19 | 34 | 72 |
| 21 | 1140558 | " " " | " " " | " | +0.82 | 0.84 | —0.01 | +7.23 | —0.05 | —0.50 | 10.4 | 23 | 19 | 29 | 71 |
| 22 | 1056237 | " " " | " " " | " | —1.27 | 0.50 | —0.19 | —0.66 | +0.39 | +4.34 | 9.1 | 30 | 7 | 33 | 70 |
| 23 | 1056226 | " " " | " " " | " | +0.65 | 0.91 | +0.03 | +1.55 | —0.46 | —6.27 | 10.6 | 22 | 18 | 30 | 70 |
| 24 | 1140586 | " " " | " " " | " | —2.40 | 0.51 | +0.12 | +2.51 | —6.36 | —5.71 | 13.2 | 30 | 12 | 26 | 68 |
| 25 | 1140559 | " " " | " " " | " | +2.73 | 0.86 | —0.10 | +0.50 | +6.08 | +1.73 | 9.0 | 23 | 13 | 32 | 68 |
| 26 | 1152431 | " " " | " " " | " | +0.90 | 0.83 | +0.01 | —1.6 | —10.2 | +0.9 | 13.3 | 23 | 19 | 25 | 67 |
| 27 | 1056260 | " " " | " " " | " | —3.70 | 0.54 | —0.23 | —5.26 | —0.83 | —0.28 | 12.4 | 29 | 5 | 33 | 67 |
| 28 | 1048081 | " " " | " " " | " | —0.95 | 0.82 | —0.19 | +0.10 | —2.7 | +3.1 | 11.2 | 24 | 7 | 34 | 65 |
| 29 | 1073602 | " " " | " " " | " | +0.36 | 0.82 | +0.09 | +4.4 | —1.5 | +9.3 | 11.9 | 24 | 14 | 25 | 63 |
| 30 | 1056233 | " " " | " " " | " | —1.25 | 1.36 | +0.07 | —3.86 | —3.0 | +0.04 | 6.9 | 13 | 15 | 33 | 61 |
| 31 | 1056256 | " " " | " " " | " | +0.43 | 0.43 | —0.25 | —3.69 | — 12.59 | —4.44 | 18.5 | 31 | 3 | 25 | 59 |
| 32 | 44206 | Arnold Nicoud. | Anchor. | Breguet. | —2.84 | 1.14 | +0.22 | —6.94 | —0.59 | —6.99 | 11.7 | 17 | 5 | 27 | 49 |

TABLE No. III.—WATCH MOVEMENTS OBSERVED FOR NINETEEN DAYS, IN TWO POSITIONS, AND IN THE OVEN AND REFRIGERATOR, AND WHICH RECEIVED CLASS III. CERTIFICATES.

| Rank. | Maker's Number. | Maker's Name. | Escapement. | Spring. | Mean daily rate. | Mean variation. | Var. for 1° Fahr. | Diff. bet. pendant up and dial up. | Diff. bet. extremes of rate. | Mark computed for | | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Daily variation. | Temperature. | Position. | |
| | | | | | s. | s. | s. | s. | s. | | | | |
| 1 | 2,126 | A. Saltzman. | | | —4.87 | 0.36 | —0.06 | —5.76 | 11.0 | 33 | 16 | 29 | 78 |
| 2 | 1,686 | Geo. H. Ford, New Haven. | Lever. | | +1.38 | 0.80 | —0.004 | —4.49 | 18.7 | 24 | 20 | 31 | 75 |
| 3 | 1,144,025 | American Watch Co. | " | Flat. | +2.53 | 0.47 | —0.17 | —3.52 | 8.2 | 31 | 9 | 33 | 73 |
| 4 | 1,144,010 | " " " | " | " | —3.67 | 0.95 | —0.13 | —0.90 | 11.6 | 21 | 11 | 38 | 70 |
| 5 | 1,144,277 | " " " | " | " | +2.25 | 1.05 | —0.08 | +1.71 | 5.9 | 19 | 15 | 36 | 70 |
| 6 | 1,152,185 | " " " | " | " | +6.33 | 0.79 | —0.004 | —8.0 | 10.6 | 24 | 20 | 24 | 68 |
| 7 | 1,552,582 | " " " | " | " | —3.80 | 0.91 | —0.17 | —1.8 | 7.1 | 22 | 9 | 36 | 67 |
| 8 | 1,149,688 | " " " | " | " | +0.20 | 1.19 | —0.09 | +1.58 | 8.8 | 16 | 14 | 37 | 67 |
| 9 | 1,144,280 | " " " | " | " | —0.13 | 1.18 | —0.08 | +3.0 | 11.8 | 16 | 15 | 34 | 65 |
| 10 | 1,073,609 | " " " | " | " | —0.02 | 1.16 | —0.08 | —3.84 | 8.5 | 17 | 15 | 32 | 64 |
| 11 | 1,144,064 | " " " | " | " | +0.97 | 0.82 | —0.26 | —2.20 | 13.6 | 24 | 3 | 36 | 63 |
| 12 | 1,073,610 | " " " | " | " | —4.73 | 0.75 | 0.10 | —8.4 | 10.4 | 25 | 13 | 23 | 61 |
| 13 | 1,152,119 | " " " | " | " | +2.35 | 0.77 | —0.08 | —10. | 13.6 | 25 | 15 | 20 | 60 |
| 14 | 1,152,138 | " " " | " | " | —4.22 | 1.07 | +0.11 | —8.9 | 12.5 | 19 | 13 | 22 | 54 |
| 15 | 1,149,687 | " " " | " | " | —6.86 | 1.38 | +0.23 | —2.59 | 11.6 | 12 | 5 | 35 | 52 |
| 16 | 1,444,213 | " " " | " | " | +3.11 | 1.92 | +0.03 | —6.3 | 21. | 2 | 18 | 27 | 47 |

No. 2 was deposited by its present owner. The parts of the movement were made by Patek, Phillipe & Co.

In the preceding tables where two watches have received the same mark, that one is placed first which has the smaller mean daily variation. In table I. it is difficult to say which watch should be third, and which should be fourth. The marks for the two agree within a fraction, but in favor of the watch No. 999931 made by the American Watch Company.

In order to reduce all of these watches to the same basis of comparison the numbers given in the tables have been recomputed from the original rate observations. In the first certificates issued by us it was customary to compute the mean daily variation including the days on which a change in position occurred and the numbers given for these watches will be found slightly changed from those given on the original certificates. This is owing to the fact that the mean daily variations are now computed excluding the days on which a change of position took place. The general principle on which the marks have been assigned is that in use at the Geneva observatory.

The following table analyses the total number of watch movements received to this time.

Total number received* 221.

| | | | |
|---|---|---|---|
| Number receiving class I. certificates, | 22 | |
| " " " II. " | 32 | |
| " " " III. " | 16 | |
| " " " IV. " | 33 | 102 |
| " returned to senders without certificates, | | 116 |
| " on hand, | | 2 |

The circular sufficiently explains the general condition on which the observatory issues certificates with time-pieces sent

* The following table shows the number of time-pieces received for certificates at the Neuchâtel Observatory during the past five years. The number received at Geneva was somewhat less.

| Year | 1875 | Mean Daily Varia. | 1876 | Mean Daily Varia. | 1877 | Mean Daily Varia. | 1878 | Mean Daily Varia. | 1879 | Mean Daily Varia. |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Number | 270 | | 316 | | 286 | | 330 | | 165 | |
| Number receiving Certificates | 231 | s. 0.46 | 260 | s. 0.53 | 220 | s. 0.51 | 267 | s. 0.60 | 128 | s. 0.61 |
| Class A. (Marine Chronometers) | 4 | 0.32 | 2 | 0.12 | 8 | 0.14 | 6 | 0.14 | 7 | 0.16 |
| Class B. (Pocket Watches) | 29 | 0.41 | 41 | 0.41 | 45 | 0.42 | 65 | 0.50 | 24 | 0.48 |
| Class C. (Pocket Watches) | 119 | 0.46 | 147 | 0.52 | 128 | 0.53 | 127 | 0.61 | 53 | 0.64 |
| Class D. (Pocket Watches) | 79 | 0.49 | 70 | 0.64 | 39 | 0.63 | 69 | 0.72 | 44 | 0.73 |

here for examination. In order to comprehend the relation existing between our certificates and those issued from European observatories, it will be necessary to tabulate the conditions now existing at the two principal observatories which issue watch certificates. From the "Règlement pour L'observation des Chronomètres a L'Observatoire Cantonal," issued "Au nom du conseil d'Etat," and dated "Neuchâtel, le 31 mars 1877," and from the "Règlement relatif au dépot des Chronomètres a L'Observatoire de Genève," and which bears the endorsement, "Approuvé en séance du Conseil d'Etat du 19 Décembre, 1879" we derive the following data for comparison.

In the regulations of both observatories, the first class is devoted to marine chronometers observed in one position.

ORDER AND NUMBER OF DAYS IN THE TESTS APPLIED TO TIME PIECES AT THE NEUCHÂTEL (CANTONAL) OBSERVATORY.

| Test No. | Position and Temperature. | Class of Certificate. A | B | C | D | |
|---|---|---|---|---|---|---|
| 1 | Dial up. Ordinary temperature, | 60 | 13 | 14 | 15 | * The chronometer is placed several days in the oven, which are deducted from the 60 days. |
| 2 | " Oven, | * | 1 | 1 | | |
| 3 | Dial vertical. Pendant up. Ordinary, | | 14 | 15 | | |
| 4 | " " left. " | | 2 | | | |
| 5 | " " right. " | | 2 | | | |
| 6 | Dial down. Ordinary, | | 2 | | | |
| 7 | " up. " | | 8 | | | |
| | Total number days, | 60 | 42 | 30 | 15 | |

ORDER AND NUMBER OF DAYS IN THE TESTS APPLIED TO TIME PIECES AT THE GENEVA OBSERVATORY.

| Test No. | Position and Temperature. | Class of Certificate. | A | B | C | |
|---|---|---|---|---|---|---|
| 1 | Dial vertical. Pendant up. Ordinary, | | 5 | 14 | 8 | * The order of these tests is only limited by the general consideration that the refrigerator test shall not commence for some weeks after the chronometer has been running dial up, and that a 5 day period at ordinary temperature shall intervene between the refrigerator test and that in the oven. |
| 2 | " " right. " | | 5 | | | |
| 3 | " " left. " | | 5 | | | |
| 4 | Dial up. Refrigerator about 37°, | *5 | 5 | 1 | | |
| 5 | " Ordinary, | 65 | 5 | 14 | 8 | |
| 6 | " Oven about 87°, | 5 | 5 | 1 | | |
| 7 | Dial down. Ordinary, | | 5 | | | |
| 8 | " vertical. Pendant up. Ordinary, | | 5 | | | |
| | Total number days, | 75 | 40 | 30 | 16 | |

PERFORMANCE NECESSARY TO ENTITLE TIME PIECES TO CERTIFICATES.

| | Neuchâtel. Seconds. | Geneva. Seconds. |
|---|---|---|
| 1. The variation of rate from one day to the day following, while the time piece is in the same position, must not exceed . . . . . . . | 2 | |
| 2. The variation of rate must not exceed, per degree Fahrenheit, . . . . . . . . | 0.28 | 0.28 |
| 3. The variation of rate between the positions Dial up, and Pendant up must not exceed . . . | 10 | 9 |
| 4. The daily rate must not exceed . . . . | 10 | |

The maximum difference between the daily variation for any day and the mean daily variation for the period during which the watch remains in the same position, must not exceed $1^s.5$ at the Geneva observatory.

From an inspection of these tables it will be seen that the requirements for our certificates differ somewhat from those at Neuchâtel, and very much from those at Geneva. Our class I. is similar to the highest class (B) of Neuchâtel, except that we have added the requirement that the watch shall be tested in the refrigerator as well as in the oven. The length of time is the same as at Neuchâtel, and we require two days more than at Geneva. In all three observatories the watches are tested in five positions. Our class II. requires three more tests than the corresponding class C of the Neuchâtel observatory, and two more than those of the class B at Geneva, namely: the position tests "pendant right" and "pendant left," and (as compared with Neuchâtel) the refrigerator test. On the other hand, our trial is eight days shorter than theirs.

Our class III. has no corresponding class at Neuchâtel, but has the same position tests as the class C at Geneva. The length of the trial is two days longer than at this latter observatory, and the refrigerator and oven tests are obligatory. At Geneva the oven test is applied if desired.

Our class IV. is similar to the Neuchâtel class D, except that ours is three days shorter, and the test is made either pendant or dial up as is desired.

In arranging our regulations we were influenced by two conditions. 1°. To have them as rigorous as those in use in the foreign observatories. 2°. To make the trials as short as possible consistent with thoroughness. We relied very largely

on the experience of the foreign observatories in this work, since nothing of the kind had been attempted in our own country. Our first year's experience leads us to suggest the following changes in our regulations. 1°. That the conditions for obtaining the class I. certificate be made to conform to the conditions now holding at Geneva. The tests of two days' duration are too short to accurately determine the watch's performance. By taking the time from the tests which are unnecessarily long, and adding it to the shorter ones, we can divide the time into equal periods of five days each. It is the class I. certificates which are most sought for by those makers producing accurate watches, and about whose results there is sure to be much discussion as the competition of horological industries increases. 2°. That our requisition that watches have a smaller rate than $10^s$ be abolished, 3°. That instead of allowing a single two second variation in a watch's rate to deprive it of its certificate, that the amount be lessened to 1½ seconds, but with the understanding that this is to be the limit of any daily variation from the mean of its variations from one day to the next in a given position and temperature.

We have refused certificates to several movements during the past year, which were better in their adjustments for position and temperature than some of those receiving class I. certificates, because of the largeness of their rates. The excess of $0^s.1$ or $0^s.2$ over $2^s$., which now sometimes causes a watch to lose a high class certificate, is often due to such a cause that in the mean of several observations its effect would be destroyed.

Efforts have been made (and indeed are now in progress) from time to time to have the conditions uniform at Geneva and Neuchatel. It is much to be desired that the observatories issuing watch certificates, should agree upon a common system not only of minimum requirements, but of marking the qualities of watch movements so that the certificates may be readily comparable.

We should also, in my opinion, adopt the custom which has grown up in the European Observatories which undertake the testing of time-pieces, of specializing those watches which the annual trial shows to be master pieces of horological workmanship, in such a manner that the artisans, to whom the

production of such time-pieces means years of conscientious labor, may be publicly commended. We might, for instance, issue to the first six watches in the order of their rank in the table of class I. certificates, and the first three watches in the other tables, given in your Astronomer's annual report, special certificates of merit which should name the order in which each watch stood in the trial of that particular year, with the details of the trial. We should then publish in extenso the daily rates and variations of such watches during the period of their trial. A certain minimum of performance should be exacted of every watch movement which receives one of these special certificates of merit: and I recommend that your Astronomer be empowered to invite the views of those gentlemen who are actively interested in the production of time-pieces for use in the United States, as to how far it may be desirable to modify the conditions of such trials now existing at Geneva and Neuchatel, to encourage the production of watches best adapted to our National use. The conditions of these trials should be made known by September of this year.

### THE STATE TIME SERVICE.

After the work had been fairly started of rating time-pieces, the local time service for New Haven which had been contemplated in the first plans of the Observatory, was put into operation. For the purpose of establishing uniformity in public time the following named firms make an annual subscription to the Observatory funds, and we have placed in their respective places of business telegraph instruments which continuously repeat the beats of the Observatory clock.

| | |
|---|---|
| J. B. Sargent, Esq., | B. Shoninger & Co., |
| O. B. North & Co., | The City Bank of New Haven, |
| Mallory, Wheeler & Co., | E. M. Reed, Esq., |
| Henry Hooker & Co., | W. & E. T. Fitch. |

In addition to these gentlemen the jewelers of New Haven availed themselves of the Observatory time, and this support enabled the Observatory to commence its public time service. Mayor Bigelow assumed the responsibility of setting the City Hall clock to the time of the Observatory which for reasons given further on is the local time for New York City Hall. It was a gratifying circumstance that he should subsequently,

in his capacity as Governor of the State, have signed the bill making this the standard of time for the whole State.

The extended use made of the Observatory time by the New York, New Haven & Hartford R. R., and all its divisions,

The Naugatuck R. R.,

The Boston & New York Air Line R. R.,

The Connecticut Western R. R., and

The Connecticut Valley R. R., and the manifest injustice of allowing the expense to devolve on the Observatory, lead to the consideration of the question as to the expediency of making it a subject of State legislation. This would imply the organization of a Public State Time Service—the first in this country—after the model of the government services abroad. It was an open question as to whether our people were sufficiently educated to appreciate the public economy of having the State governed by a common time. A conference with the leading Railroad men of this State, led to their cordial support of the plan proposed by the Observatory; prominent legislators in the two parties in the State legislature, after due explanations on our part, were persuaded that it would be to the material advantage of the people to have an accurate standard of time, and with this encouragement we undertook what seemed at first a discouraging task. After two hearings before the Railroad Committee, and after various measures making the service more convenient to the Railroads now using Boston time had been adopted by us, the accompanying bill was unanimously passed by both houses upon the recommendation of the Railroad Committee.

## AN ACT

### ESTABLISHING A STANDARD OF TIME.

General Assembly,

January Session, A. D. 1881.

*Be it enacted by the Senate and House of Representatives in General Assembly convened:*

Section 1. The standard of time for the meridian of the city hall, in the city of New York, shall be and is hereby made the standard of time for this State.

Sec. 2. To enable this standard of time to be accurately determined and furnished each day the comptroller of this

State is hereby authorized to contract with the corporation known as "The President and Fellows of Yale College in New Haven" at a sum not exceeding two thousand dollars a year to furnish such time at least once every day (except Sunday) to the New York, New Haven and Hartford Railroad Company, at their depot at New Haven, to be transmitted by telegraph by said railroad company, as railroad business, over its entire line and to all other railroad companies in this State connecting with said railroad.

SEC. 3. It shall be the duty of every railroad company in this State upon receiving such standard of time to transmit the same by telegraph, as railroad business, each day to all their depots having telegraphic communication, and to all other railroads having connection with them, and to keep at such depots a clock regulated by said time.

SEC. 4. This bill shall take effect on its passage.

The arguments adduced by the Observatory in favor of the bill are to be found in the Railroad Commissioners'* report for 1881, p. 57, and are here in part repeated. The bill was signed by the Governor of the State on March 10, 1881.

1st. "Connecticut is essentially a manufacturing center. There are many thousands of persons engaged in her factories upon whose precision and economy of time the success of the State in her struggle for trade must ultimately depend. Any service which will train these persons into habits of punctuality, and which will affect all employers and all employés with the same strict impartiality, so far as wages for time employed is concerned, will be a great benefit to the State in the amount of money actually saved to it, and in the satisfaction which is felt by the employés of large corporations that the time kept is beyond any question.

2d. "There are large financial interests centered in the insurance, banking and brokerage offices in the State which are directly hampered by having no fixed times for office opening and closing. The meeting of an obligation held by a person in New Haven may fail because the payee in Hartford thinks

* To the Honorables George M. Woodruff, John W. Bacon, William H. Hayward, railroad commissioners for the State of Connecticut, is largely due the credit of establishing precedent legislation in the United States on the subject of railroad time.

from his watch the New Haven bank is closed, when in reality there remains time for a telegraphic transfer of funds.

3d. "The numerous annoyances caused to the traveling public by the changes of time at various stations, and the business engagements broken from a lack of common time, annually make up a large financial loss to the community, in addition to the vexation of mind. Not infrequently legal questions depend for their right adjustment on the time of day at which a particular event occurred, and the authority of the time-pieces in use in different places becomes one of exceptional interest. Notably has this been the case in the question of contested elections, where the closing of the polls at a particular instant has been the means of excluding voters who felt they still had the right of placing votes.

4th. "A careful canvass of the railroad superintendents of New England shows that it is almost their unanimous opinion that such a service directly conduces to the safety of travel, and it is entirely unanimous on the part of the railroads transacting a large business. Not only does such a service add to the public safety by the direct starting and stopping of the trains, but by the education which it encourages among all the railroad employés in the subject of accurate time.

"It is always felt that the real safety of railroad travel depends not wholly upon the methods of signaling, or the stringent rules of a company, or upon the various mechanical appliances in use for lessening the amount of work left to human judgment, though each of these agencies contributes a part to this safety, but it does depend to a very large degree upon the education, experience, and fidelity to duty of the employés who have the actual running of trains under their charge. Now it is the practical result of such a public time distribution as Yale has undertaken that there is a certain emulation fostered among the employés as to the accuracy and time-keeping qualities of their watches. The fact that at certain times every day at every station of their road the observatory standard time-signals will come with unerring precision, the feeling of the responsibility which they incur by refusing to avail themselves of the daily time-signals, the personal pride they have in being authorities on the subject of correct time, the opprobrium cast upon them by their associates if they neglect to take such a simple precau-

tion as to examine their watches at every opportunity because of the risk they expose their associates to,—all these reasons operate in practice to instill accuracy in time as a matter of habit." *

It is apparent that to obtain the State aid in succeeding years, our service must be so popularized that the people may readily understand and obtain our time signals. Accordingly we have allowed the Connecticut Telephone Company to bring their wires into the Observatory and there be directly connected with our clock. They offer our time signals to any of their subscribers outside of New Haven. They have already established a time ball at Hartford and contemplate establishing several others in the State. At New London harbor we are completing arrangements for the firing of a time gun. The work of extending the signals over the various railroad telegraphs of Western New England is making satisfactory progress. Circulars are displayed in local telegraph stations for the information of the public and railroad employés.

The observations of stars necessary in the Horological Bureau have been made on 327 nights between the dates of January 1st, 1880, and June 1st, 1881, as follows:—

| | | Nights Observations. | | | Nights Observations. |
|---|---|---|---|---|---|
| 1880. | January, | 16, | | October, | 20, |
| | February, | 23, | | November, | 21, |
| | March, | 18, | | December, | 19, |
| | April, | 22, | 1881. | January, | 19, |
| | May, | 22, | | February, | 17, |
| | June, | 20, | | March, | 15, |
| | July, | 13, | | April, | 22, |
| | August, | 20, | | May, | 17, |
| | September, | 20, | | | |

which gives an average interval of about 1½ days between consecutive clock error determinations. The collimation and local errors of the transit being observed directly, it is customary, where practicable, to observe two stars such that the

$$\mathrm{Tan}\,\delta - \mathrm{Tan}\,\varphi = \mathrm{Tan}\,\varphi - \mathrm{Tan}\,\delta'$$

of Hansen's formula. From manuscript tables the clock correction may then be quickly computed.

It is desirable that some understanding be reached among the observatories distributing time signals, regarding the meridians to be employed. The use of the two standards of time, New York and Boston, over so small a range of longitude as New England, is hardly to be commended. Very little

* See Appendix.

can be urged in favor of the continuance of the present system by which Boston time is furnished to Western New England, and New York time is carried northward and eastward where it frequently crosses the Boston service and we have the community in the unpleasant position of using one local and two railroad times. My own views have been elsewhere expressed.*

THE THERMOMETRIC BUREAU.

Availing ourselves of a grant from the Board of Directors of the Bache Fund of the National Academy of Science, Professor Newton was able to secure, in his visit to Europe in 1880, a number of high grade standard thermometers. Through the kindness of E. M. Whipple, Esq., at the Kew Observatory, Dr. Neumeyer at Hamburg, and Drs. Foerster and Thiesen at Berlin, many of these standards were carefully compared and investigated abroad. In June of 1880, we had sufficiently progressed in the construction of our comparators and other accessory apparatus to issue the following circular† explanatory of the objects and conditions of our work.

*Circular of the Thermometric Bureau.*

This Bureau has been established by the Corporation of Yale College, at the recommendation of the Board of Managers of the Winchester Observatory, in order to afford desired facilities for the adequate verification of thermometers.

Thermometers will be received by the observatory for the purpose of comparison with the observatory standards, and certificates of comparison signed by the Astronomer in charge will be issued with thermometers so compared. These certificates will contain a statement of the corrections to be applied at intervals of five or ten degrees of the thermometer scale to cause it to have the same reading as the observatory standards. In general these corrections will be expressed in tenths of one degree.

Thermometers sent for verification must have a name and number engraved upon them; and thermometers which are not graduated on the glass

* North Amer. Rev., Dec. 1880. The Nation, May 12, 1881.

† *The title page reads: Circular of the Thermometric Bureau. Published by the Observatory Board of Managers, for the information of persons interested in this public service. The Express address is the "Winchester Observatory of Yale College, New Haven, Conn." The Observatory P. O. Box is No.* 853. *New York makers desiring to send thermometers by hand may do so by leaving them with Lockwood's private express, care Oelschlaeger Bros.,* 162 *William Street. To insure the safe transmission of thermometers by express, they should be placed in two boxes, one inside the other, and the space filled with cotton-wool or its equivalent. Single clinical thermometers may be packed in wooden boxes and sent by mail.*

stem must be of sufficiently good workmanship to satisfy the observer in charge that the scale will not suddenly change with reference to the glass stem of the thermometer tube with ordinarily careful usage.

The Board of Managers have established the following scale of charges for this service, which includes certificate:—

| | |
|---|---|
| Standard Meteorological Thermometers with independent freezing point determination, | $2.00 |
| Standard Meteorological Thermometers, | 1.00 |
| Ordinary Meteorological Thermometers, | .50 |
| Ordinary Maximum Thermometers, | .75 |
| Ordinary Minimum Thermometers, | .75 |
| Clinical Thermometers, | .50 |

There will be a deduction of one-fifth of the above charges where more than eight thermometers of one kind are received at the same time. In the case of clinical thermometers the charge will be four dollars per dozen when not less than two dozen are sent at the same time.

For other thermometers than the above the charges for verification will be furnished on application.

The letter of advice accompanying thermometers sent for verification should contain the maker's name, the number of each thermometer, and full directions for reshipment.

All proper precautions are taken by the Board of Managers to guard against loss or injury; but as it is manifestly inexpedient that a University Corporation should be responsible for property in its care for such a purpose, it is to be understood that all risks are assumed by the person sending the thermometers. LEONARD WALDO, *Astronomer in Charge.*

Approved and ordered to be published by the Board of Managers of the Winchester Observatory.

C. S. LYMAN, *President.* H. A. NEWTON, *Secretary.*

New Haven, Conn., June 1, 1880.

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The meteorological observers in this country have now no common standard of easy access; and it seems eminently proper that the observatory should undertake to be useful to these observers and afford the means of comparison desired. With this end in view, the observatory has accepted the aid of the Board of Directors of the Bache Fund of the National Academy in obtaining the standards of the foreign observatories, and has made provision for the constant determination of the errors of the standards themselves.

Statistics show that several thousand thermometers of refined construction, and graduated on the stem to 0°.2 F. or thereabouts, are annually procured by the medical practitioners of our country for physiological researches and daily practice. The majority of these thermometers are newly made (within six months), and their verification depends on inferior (from the scientific standpoint) thermometers in the hands of individual makers It is needless to say that the readings of such thermometers have little value

in indicating the true temperature of a patient, or affording data in cases which the physician wishes to describe in print.

In order to encourage the manufacture of thoroughly seasoned thermometers for physicians' use, the observatory will receive from the makers thermometer tubes which have been numbered but not graduated, and will seal such tubes in boxes in such a manner that they can only be opened by breaking the seals. After not less than one year the boxes may be opened by an observatory officer, and in the certificates of verification furnished with these thermometers the length of time they have been under the observatory seal will be stated. The observatory charge for recording and sealing such thermometers will be $1.00 per hundred, and makers desiring to avail themselves of this privilege will send such boxes to the observatory for sealing.

The observatory will make arrangements with hospitals and other institutions using a number of thermometers, for the systematic examination at stated intervals of all thermometers in their use. Such an arrangement precludes errors arising from the use of newly made instruments which have been verified, but whose scales have not yet attained an approximately permanent position.

The certificates issued with registering clinical thermometers states the corrections to be applied at each fifth degree of their scales, in order that the corrected readings may indicate the true temperature. It is recommended that the graduation of thermometers intended for certification be in fifths of one degree.

Ordinary and clinical thermometers are returned within three days from the time of their reception, if the observatory charges are remitted with the thermometers.

In case they are not so remitted, they are payable upon notification by the observatory that the thermometers are ready to be returned.

## DEFINITION OF THE YALE STANDARD THERMOMETER.

The theoretical mercurial standard thermometer to which thermometers are referred, is graduated by equal volumes upon a glass stem of the same dimensions and chemical construction as the Kew standards 678 and 584. The permanent freezing point is determined by an exposure of not less than 48 hours to melting ice, supposing the temperature of the standard has not been greater than 25° C.=77° F. during the preceding six months. The boiling point is determined from the temperature of the steam of pure water at a barometric pressure of 760 mm.=29.922 in., (reduced to 0° C.) at the level of the sea and in the latitude of 45°. This standard is probably within ±0°.03 C. of the perfect gas thermometer between 0° and 100° C. The exact difference is in process of determination.

## OBSERVATORY APPARATUS FACILITATING THE INVESTIGATION OF THERMOMETER ERRORS.

1°. Horizontal comparator and graduating machine for the calibration and graduation of standards. Wm. Grunow, maker.

2°. Small cathetometer, millimetre graduation, 220 mm. in length. Wm. Grunow, maker.

3°. Standard Barometer, "Jas. Green, N. Y., 957." Mercury column about 0.50 in. internal diameter.

4°. Freezing point apparatus. Capacity of protected inner chamber, 2 liters.

5°. Regnault's boiling point apparatus, constructed of brass; will immerse in steam thermometers 40 cm. long.

6°. Boiling point apparatus entirely of glass; will immerse in steam thermometers 64 cm. long.

7°. Pierre's water comparator, arranged for all temperatures between 0° and 100°; will immerse in water or steam thermometers 64 cm. long.

8°. Copper air-jacketed comparator for the comparison of clinical and ordinary thermometers; capacity 64 stem graduated thermometers.

*The following standards will be used by this department of the Observatory for the verification of thermometers:—*

| DESIGNATION. | MAKER. | MAKER'S NUMBER. | HOW GRADUATED. | LENGTH OF 1°. | SMALLEST GRADUATION. | LENGTH OF TUBE. | SHAPE OF BULB. | REMARKS. |
|---|---|---|---|---|---|---|---|---|
| Standard Air Thermometer. | | | | | | | | |
| Primary Standard. | Kew Observatory. | 585 | −84° to +275° C. | 1.73 mm. | 1° | 618 mm. | Cylindrical. | Kew Observatory, 1880. Filled in 1874. |
| " " | Kew Observatory. | 578 | − 9 to +105 C. | 8.46 " | 0.5 | 455 " | " | Kew Observatory, 1880. Filled in 1874. |
| " " | Kew Observatory. | 584 | +14 to +220 F. | 1.87 " | 1 | 455 " | " | Kew Observatory, 1880. Filled in 1874. |
| " " | Casella, London. | 85247 | +30 to +214 F. | 1.38 " | 1 | 390 " | " | Filled in 1867, Graduated 1879. |
| " " | R. Fuess, Berlin. | 89 | − 6 to +105 C. | 4.15 " | 0.1 | 650 " | " | Patent, 1877. |
| " " | R. Fuess, Berlin. | 50 | − 2 to +105 C. | 4.05 " | 0.2 | 578 " | " | Patent, 1877. |
| " " (Five). | Baudin, Paris. | | C. | | 0.1 and 0.2 | | | ** |
| " " | Fastré Ainé à Paris. | *594 | −13 to +85.6 C. | 3.62 " | * | 550 " | " | Filled in 1854. |
| " " | Fastré Ainé à Paris. | *596 | −35 to +84.2 C. | 2.60 " | * | 508 " | " | " " 1854. |
| Four Standards. | Tonnelot à Paris. | 2584 to 2587 | + 5 to +230 F. | 1. 8 " | 0.5 | 455 " | " | " " 1879–4. |
| Secondary Standard. | Casella, London. | 35242 | +10 to +215 F. | 1.59 " | 1 | 378 " | " | Filled in 1867. Graduated 1879. |
| " " | Casella, London. | 35346 | +27 to +212 F. | 1.85 " | 1 | 382 " | " | Filled in 1867. Graduated 1879. |
| " " | Fuess, Berlin. | 536 b. | −24 to + 55 C. | 2.44 " | 0.2 | 302 " | Spherical. | |
| " " | Greiner & Geissler, Berlin. | 601 | −19 to + 45 C. | 3.94 " | 0.2 | 245 " | " | Date 1878 on the Scale. |
| " " | Greiner & Geissler, Berlin. | 508 | −27 to + 50 C. | | 0.2 | 298 " | " | |
| " " | F. G. Greiner. | 600 | − 1 to + 27 R. | 9.50 " | 0.1 | 418 " | Cylindrical. | Date 1852 on the Scale. |
| " " (Two). | Baudin, Paris. | | F. | | 0.5 | | | ** |
| Comparison Thermometers. | | | | | | | | |
| Four. | J. Hicks, London. | | | | | | | ** |
| Six. | Casella, London. | Various Numbers. | −20 to +133 F. | about 1.7 mm. | 1 | 200 " | Spherical. | |
| One. | Fuess, Berlin. | 59 | − 8 to +105 C. | 2.27 " | 1 | 299 " | Cylindrical. | |
| — | Baudin, Paris. | | | | | | | ** |
| Clinical Thermometers. | | | | | | | | |
| Four. | J. Hicks, London. | | | | | | | ** |
| Four. | Casella, London. | Various Numbers. | +80 to +130 F. | about 3.5 " | 0.2 | 253 " | Cylindrical. | |
| Two. | Fuess, Berlin. | 84 and 85 | +26 to + 46 C. | about 7.2 " | 0.1 | 238 " | " | |
| Self-Registering Thermometer. | Casella, London. | 9738 | −15 to +135 F. | 1.69 " | 1 | 308 " | Spherical. | Maximum. |
| " " " | Casella, London. | 9960 | −25 to +120 F. | 1.66 " | 1 | 357 " | " | Minimum (spirit). |

Besides these there are some twenty-five thermometers, by various reputable makers, self-registering and otherwise, to be used as occasion requires.

* Loaned from the Physical Laboratory of Professor Arthur W. Wright. Arbitrary graduations. **Not yet received.

In accordance with the terms of the circular the Observatory has issued with thermometers sent here to be examined, a total of 1957 certificates, which may be grouped as follows:

20 certificates with mercurial thermometers of the highest class of construction, and requiring for the data used in their preparation a period of from four to six weeks. This class includes the standard of the United States Coast Survey, of the U. S. Army Signal Service, and of several institutions and persons possessing standard thermometers.

12 certificates with Yale standard minimum alcohol, ethyl oxide and carbon disulphide thermometers designed for the Arctic explorations undertaken by the U. S. Army Signal Service.

250 certificates with Meteorological standards (63 alcohol and 187 mercurial) for Meteorological observations.

8 certificates issued with thermometers designed for temperatures above 212° F.

1667 certificates with thermometers designed for physicians use and physiological research.

The rapid success of our thermometric work is a cause of congratulation. The makers, at first viewing our efforts with suspicion and in some cases sending thermometers we had examined to Kew to be retested, have accepted the authority of our Observatory as final, and have greatly improved under our encouragement. This is particularly true of the important class of makers of physicians' thermometers, to whom we have loaned standards and taken every occasion to educate and advise with. This great improvement is strikingly illustrated by the fact that while in June, 1880, four-fifths of all the thermometers received (representing seven different makers) were in error over one-third of a degree, and two per cent. had errors exceeding a whole degree, in April and May 1881, four-fifths of all the thermometers sent had errors less than three-tenths of one degree. The medical press has, without any exception to our knowledge, commented favorably on this branch of our service and urged it upon its professional readers. It is with feelings of surprise, however, that we have received in the course of the year, perhaps, fifty thermometers taken from active practice whose errors exceeded

a degree and a-half. There have been, comparatively, but few physicians' thermometers made in this country which have united accurate graduation of the scale with the requisite age of tube necessary to preclude further sensible changes, and there is little doubt that the great majority of physicians' thermometers now in use in the United States are from one-half to two degrees too high in their indications. The clause in our circular for the encouragement of those makers who will take the pains to properly season their thermometers, has been made use of by one house, and I am informed of others who have thermometer tubes in process of manufacture to remain under our seal for a year or more before graduation.

We are also called upon from time to time to compare aneroid and mercurial barometers with our standards.

The investigation of our own standard thermometers has, however, been the most laborious work, and has occupied all the time not devoted to the examination of other thermometers. At the request of the Signal Service of the Army we have designed various forms of thermometers for meteorological and comparison purposes. Several of these forms have been put on sale by the firm of J. & H. J. Green, New York, and doubtless they will find acceptance for scientific use. A large comparator, designed for the comparison of standards for the Signal Service has been built under our direction and is now at the Observatory undergoing a trial.

For convenient reference I append in a foot note* the statistics of the Kew Observatory examinations of thermometers for the five years ending 1879.

THE ASTRONOMICAL WORK.

Although our limited force has been very fully occupied with the work described, yet there has been found time to undertake the following additional work in Astronomy:

* Thermometers examined at the Kew Observatory.

| | 1875 | 1876 | 1877 | 1878 | 1879 |
|---|---|---|---|---|---|
| Thermometers, Ordinary Meteorological, | 1238 | 1410 | 1428 | 1435 | 1286 |
| Boiling Point Standard, | 64 | 36 | 57 | 47 | 67 |
| Mountain, | 20 | 34 | 22 | 16 | 43 |
| Clinical, | 1439 | 1560 | 2281 | 2032 | 3405 |
| Solar Radiation, | | 90 | 75 | 65 | 27 |
| Total, | 2761 | 3130 | 3863 | 3595 | 4828 |
| Total number barometers examined, | 214 | 230 | 209 | 222 | 196 |

1°. The reduction of the observations made by Mr. Seagrave and myself at Providence, R. I., to determine, if possible, the parallax of Θ Cassiopeiae. This work, undertaken by Messrs. Kershner and Little gave, in their hands, a small negative parallax.

2°. A series of longitude signals have been exchanged with the observatory of Harvard college. Professor W. A. Rogers of Harvard University exchanged instruments with me on three nights. The reductions are very nearly completed in the hands of Mr. Kershner.

3°. A number of double stars have been measured, and the Fauth micrometer has had its constants accurately determined.

4°. The facilities of the clock-room were placed at the disposal of Professor Cleveland Abbe, of the Signal Service of the Army, for a series of observations with the reversible pendulum. The series is now being continued by Mr. Sherman. Several new pieces of apparatus have been devised for use in our current work. A new apparatus for sending time-signals, capable of easy adjustment and repair, and entirely exterior to the clock case, has been made from our designs by the Messrs. Howard. An apparatus for measuring the arc of pendulum vibrations by electric contact, and made by William Grunow, has been provided and considerable progress has been made by the same mechanician on a horizontal comparator for thermometer calibration and graduation.

## GIFTS.

The following named gentlemen and corporations have shown such favors to the observatory that it is proper they should be mentioned in this place, and their kindness gratefully acknowledged.

R. L. Worthington, Esq., of Cincinnati, for the pair of transit collimators.

Dr. Wm. Hillhouse, of New Haven, for the gift of the Hillhouse clock, and the Hon. Jas. E. English, for assuming a part of the expense of its construction.

Professor E. C. Pickering, director of the observatory of Harvard college, for facilities granted during the exchange of longitude signals.

R. P. Cowles, Esq., of New Haven, for the copper thermometer comparator.

Judge L. B. Morris, of New Haven, and His Honor Robert C. Coit, Esq., of New London, and to other members of the State Legislature, for their active interest in extending the work of public time distribution undertaken by the observatory.

The Board of Directors of the Bache Fund of the National Academy for a grant of $500, to procure certain instruments necessary in the establishment of a bureau for thermometic researches.

The Western Union Telegraph Company, for the free use of their wires for longitude purposes, and the use of certain telegraph poles (for a limited period) near New London.

The Clark chronograph, which has been steadily in use in rating watches, is loaned by Mr. Beebe.

The following named gentlemen have been connected with the observatory during the past year:

Mr. William Beebe, assistant in the Horological Bureau, who has had charge of the determination of clock errors and of the rating of watches, and who prepared the tables of watch rates given in this report.

Mr. O. T. Sherman, Mr. J. E. Kershner and Mr. C. N. Little, have been occupied in various parts of the observatory work. Mr. Sherman principally in connection with Thermometry. Messrs. Kershner and Little in connection with the longitude determination and work with the Equatorial telescope of the Sheffield Scientific School. These two latter gentlemen left us during the year to accept positions elsewhere. The faithful diligence of all these gentlemen has greatly contributed to the success of our year's work.

It is a great hindrance to the economical performance and scientific precision of the work we have in hand, that we are obliged to use our present quarters which require a seriously inconvenient diversion of our work. It is urgent upon us, if we wish to maintain the work we have commenced, that provision at once be made for the sheltering and proper use of the valuable instruments and standards we have gathered together, and which we cannot replace if injured or destroyed.

Respectfully submitted,

LEONARD WALDO.

NEW HAVEN, CONN., June 1, 1881.

# APPENDIX.

These and other reasons having decided our Board to undertake the public time-service, the policy and methods of performing it were adopted in accordance with the following considerations:

1st. The time furnished must be that which would be acceptable to the largest number of people. It is a matter of no importance whether the selected time be five minutes fast or slow of the time now adopted in any particular city; it is a matter of the utmost importance that it be the *same* time throughout the State. It was found in examining the matter there could fairly be but one opinion as to the time to be adopted, and that it should be the time of the metropolis of the United States, which is the time employed by four-fifths of the manufacturing and railroad interests of the State. By adopting this standard Connecticut is in sympathy with the wide expanse of territory between Buffalo and Rhode Island, and takes the first step toward dividing the country into large sections which shall have common standards of time.

2d. The time furnished must have the greatest possible accuracy. Half a minute might not be of great importance in most of the transactions of life; neither would the fiftieth of an inch be of great importance in ordinary measurements. But in such a public time-service, as in the matter of the standard yard kept at the State engineer's office, there can be no middle ground between accuracy and carelessness. If the jewelers in the various cities or the conductors of our railroads once feel that they cannot implicitly rely upon the observatory time-signals, that there may be errors of ten or fifteen or thirty seconds in them, then in any case where their own time-pieces differ much from the observatory time-signals they are in painful doubt as to which is right, and they may with some excuse decide in favor of a watch which has not before failed them. Then, too, the whole education of the people in accurate time is lost, if they cannot constantly rely on the unquestioned accuracy of the time service.

3d. The method of distribution must be as simple as is consistent with precision and certainty of understanding the signals sent, and so far as possible the ordinary telegraphic apparatus in every station should be the means of carrying the time-signals.

APPENDIX.

Early in the year the preparations were completed and the following circular was issued by the observatory.

## CIRCULAR.

### The Railroad Telegraph Service.

The distribution of the standard Time over the State at large, through the instrumentality of the Western Union Railroad Telegraphs, takes place twice a day. This distribution is automatically accomplised by the clock itself, which is put into circuit with a relay whose repeating points accomplish the distribution over any number of lines desired. The following circular, with its blanks properly filled, is posted in the principal railroad telegraph offices in Connecticut, and sufficiently explains the service to be readily comprehended by the railroad employes and the traveling public, for whose benefit the service is undertaken.

---

### YALE COLLEGE PUBLIC TIME SERVICE.

____________________ *RAILROAD STANDARD TIME.*

INSTRUCTIONS TO THE TELEGRAPH OPERATORS.

On and after__________________ the standard New York time of this Railroad will be sent by telegraph from the Winchester Observatory of Yale College to the Stations along the lines of the road, and telegraph operators will be careful to see their telegraph instruments are in readiness to receive the time signals, beginning at 7:28 a. m. and at 11:58 a. m., and continuing for four minutes in each case, according to the following schedule:

7.28 a. m. The word "Time" will be sent by the New Haven operator, and immediately thereafter the clock-beats of the Observatory clock will be sent over the various divisions of the road. These beats are for the even seconds, and for the last five seconds of each minute. Thus the telegraph instruments in the circuit give the seconds as follows: $0^s$ $2^s$ $4^s$ $6^s$ $8^s$, and so up to $50^s$ $52^s$ $54^s$ $56^s$ $57^s$ $58^s$ $59^s$ $60^s$. These beats continue until $7^h$ $29^m$ $40^s$, when there is a complete silence for $20^s$, and the first beat is for $7^h$ $30^m$ $0^s$. Then the beats continue as above until $7^h$ $32^m$, when the operator at New Haven will disconnect the instrument.

11.58 a. m. The same schedule is repeated, the beats being omitted for the twenty seconds after $11^h$ $59^m$ $40^s$, and commencing again at exactly twelve o'clock.

This standard of Time is slow of Boston $11^m$ $46^s.3$, and is fast of Washington $12^m$ $1^s.5$. It is local time for the meridian of the New York City Hall.

LEONARD WALDO,

By order Astronomer in Charge.

________________________

Supt. __________________ R. R.

It is not possible to maintain absolute accuracy in any standard clock, and queries are frequently addressed to the observatory as to the accuracy attained in this service. In reply it can only be said that the facilities at the disposal of the observatory for an accurate service are exceptional, and that the records show a favorable comparison with those of the best European services. As a rule the telegraph beats of the clock in any part of the State are exact to within less than one-third of a second, and for special scientific work the observatory will furnish, as nearly as possible for any given time, the exact error of the mean time standard in hundredths of seconds.

## THE LOCAL CITY SERVICES.

Besides the above service twice a day, the observatory has taken steps to introduce a continuous local service in those cities where any considerable number of jewelers, banks and manufacturers desire a constant regulation of the standard of Time. Where this continuous distribution takes place over the ordinary telegraph instruments, the following circular is furnished by the observatory, to be posted near the instrument:

STANDARD TIME FROM THE WINCHESTER OBSERVATORY OF YALE COLLEGE.

*The Telegraphic Instrument records the beats of the Observatory mean time standard clock at the even seconds, beating the last* 5 *seconds of each minute, and omitting the last* 20 *seconds of each five minutes.*

*This standard of Time is slow of Greenwich, Eng.,* $4^h\ 56^m\ 1^s.7$, *and of Boston,* $11^m\ 46^s.3$. *It is fast of Washington* $12^m\ 10^s.5$, *and is the standard of the meridian of the New York City Hall.*

The observatory will entertain proposals for any extension of its usefulness in respect to furnishing these standard time signals to persons or corporations so desiring.

In the New Haven local service the time signals are received continuously by the subscribers. Owing to the cost of maintaining constant telegraphic communication with other cities, it is not at present practicable to deliver the time signals to other cities except at the stated intervals of each day given in the circular of the Railroad Service. This is found to be, in practice, abundantly sufficient to allow the time-pieces to be set with the signals, or to determine their errors with exactness. It is not always possible to accommodate single jewelers at a distance from the observatory with these signals. Applications for the service, however, will always receive attention.

REPORT FOR THE YEAR 1882–1883 OF H. A. NEWTON, DIRECTOR, TO THE BOARD OF MANAGERS OF THE OBSERVATORY IN YALE COLLEGE, PRESENTED BY THEM TO THE PRESIDENT AND FELLOWS; TO WHICH IS APPENDED THE REPORT OF THE ASTRONOMER IN CHARGE OF THE HOROLOGICAL AND THERMOMETRIC BUREAUS.

We herewith transmit to the President and Fellows of Yale College, the report of the Director of the Observatory.

Respectfully,

C. S. LYMAN, *Pres.*
E. LOOMIS,
J. CAMPBELL,
T. G. BENNETT,
H. A. NEWTON.

YALE COLLEGE, June 18, 1883.

# REPORT.

GENTLEMEN:

You have personally very little need to be informed from me of the state of the Observatory. It is only since the first of May that I have been Director, and all the measures that have been adopted have been so thoroughly discussed in our meetings that you are already familiar with them. It is only in a formal way, therefore, that the present Report is addressed to you.

During the past year the Horological and Thermometric departments of the Observatory have been in successful operation. Dr. Waldo's report herewith transmitted gives in detail the account of excellent work done by him, in which he has been ably assisted by Mr. Willson and Mr Sherman.

To save the Observatory from the care of telegraph lines, and the manifold business complications involved in a complete public time-service an advantageous contract has been made with the Standard Time Co., by which the Observatory, after fulfilling its contract with the State, will furnish time signals to that Company to be by them distributed to parties wishing such service. This contract takes effect on the first of July.

The Heliometer which was ordered two years ago from Messrs. Repsold of Hamburg was finished and sent to us this spring. The cost of the instrument including the freight and other expenses to New Haven has been $7,461.56. Three only of the nine boxes have as yet been opened. So far as appears, the instrument, which was admirably packed by the makers, has arrived safely. Two of the micrometers have been removed from the tube, and Dr. Waldo is investigating the screws.

In preparation for the mounting of the Heliometer a dome of 15 feet in diameter was ordered from Mr.

At the Transit of Venus observations of contacts were made by so many observers as we could procure suitable telescopes for. Professors Lyman, Brewer, Wright and Beebe, Mr. Whitmore and others joined in this work.

Dr. Waldo and Professor Kershner used the Heliometer uninterruptedly during the whole time of the transit. Their observations were recorded by Prof. Phillips and Mr. Brown. These measurements, as well as others for the instrumental constants, have been placed in Prof. Kershner's hands for reduction. In this he has already made very considerable progress.

Mr. Willson arranged the mounting of the Reed telescope by removing the object glass and inserting a small uncorrected lens, for photographing the Sun during the transit. The most important novelty was the obtaining a line of reference on the photograph by the use of a mercury cistern just in front of the photographic plate, the upper free surface of the mercury being photographed at the same time with the sun. About 80 measurable plates were obtained. None of them have as yet been measured. The principal expense incurred was borne by Mr. Willson himself.

Mr. Sherman, assisted by Prof. Beebe, made use of the telescope of the Sheffield Scientific School. A set of inclined lines was inserted in the focus of the instrument and used somewhat after the manner of a ring micrometer. About 80 transits of the Sun and Venus were observed. The reduction of these observations has been essentially completed by Mr. Sherman himself, or at his own expense.

Progress has been made in computing refraction and other tables adapted to the latitude of the Observatory.

By the courtesy of Prof. Hilgard, Superintendent of the U. S. Coast and Geodetic Survey, a station of the Survey was set near the Observatory building and connected with the well-determined stations on East and West Rocks. The geodetic latitude and longitude of the middle point between the two towers are found to be, N. lat. 41° 19′ 28.48″, W. long. 72° 55′ 19.15″. The astro-

nomical latitude is probably four or five seconds less. The difference should be exactly determined during the coming year.

The house on Caner street has been nearly, and the two on Prospect street, entirely finished. The grounds around the Observatory have been plowed, harrowed, rolled and seeded. Walks and drives have been laid out under Mr. Brown's direction, and many shrubs and trees planted. The principal part of the grading of Caner street has been accomplished. The buildings and the other improvements of the Observatory property have involved heavy expense, but it is hoped that the early sale of building lots will reduce the encroachment upon the munificent endowment of Mr. Winchester to a minimum.

Mr. W. D. Ely, of the class of 1836, has given us $400 for the purchase of instruments for observing terrestrial magnetism. The instruments have not yet been received.

We owe thanks to Mr. R. M. Everit for shrubs and plants for the Observatory grounds.

Donations to the library of the Observatory have been received from the following persons:

The Director of the Observatory at Adelaide,
" " Armagh,
" " Cambridge, Mass.
" " Chapultepec,
" " Dun Echt,
" " Liepzig,
" " Palermo,
" " Pulcowa,
" " Rio de Janeiro,
" " Washington.
The Chief of Engineers, U. S. Army,
The Smithsonian Institution,
The Chief Signal Officer, U. S. Army,
Lieut. Col. Comstock, in charge of the Lake Survey,
The Superintendent of the American Ephemeris,
The Canadian Institute,
The Superintendent of the Meteorological Service, Canada,
The Lords Commissioners of the Admiralty,
The University of Tokio,
The Science Observer,

Mr. R. Brown,
" G. J. Brush,
" S. W. Burnham,
" J. Campbell,
Messrs. J. D. and E. S. Dana
Mr. J. W. Gibbs,
" A. Hall,
" J. Janssen,
" C. S. Lyman,
" C. H. F. Peters,
" E. C. Pickering,
" T. Schwedoff,
" J. Sharpless,
" O. T. Sherman,
" A. Tischner,
" L. Waldo,
" B. Weinstein.

Respectfully,

H. A. NEWTON.

YALE COLLEGE, June 18th, 1883.

THIRD

# ANNUAL REPORT

OF THE

## ASTRONOMER

IN CHARGE OF THE HOROLOGICAL AND THERMOMETRIC BUREAUS

IN

# THE OBSERVATORY

OF

# YALE COLLEGE.

1882–1883.

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PRESENTED TO THE DIRECTOR OF THE OBSERVATORY,
JUNE 18, 1883.

BY

LEONARD WALDO.

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NEW HAVEN:
TUTTLE, MOREHOUSE & TAYLOR, PRINTERS.
1883.

# THIRD

# ANNUAL REPORT.

## 1882–83.

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To the Director of the Observatory:

Sir—The present report refers to the work in the Horological and Thermometric Bureaus during the year ending May 31, 1883.

### THE HOROLOGICAL BUREAU.

The methods of comparing time pieces, of determining the errors of the standard clocks employed, and of making the records of the bureau, continue the same as in the last report. As anticipated the number of watches entered this year is not greater than last year, but they continue to be received from a variety of makers and show a decided improvement in quality of performance.

Owing to the interruptions incident to our building and moving into the new observatory on Prospect street, it was found inexpedient to alter the conditions of our watch trials. They remain therefore as they were.

The duration of the trials and the position of the time-pieces submitted during the past year are shown in the following table:—

| Test No. | Position and Temperature. | Class of Certificate. I. | II. | III. | IV. |
|---|---|---|---|---|---|
| 1 | Dial up, Ordinary, | 12 | | | |
| 2 | " Refrigerator, | 1 | 1 | 1 | |
| 3 | " Oven, | 1 | 1 | 1 | |
| 4 | " Ordinary, | | 8 | 8 | 12 or |
| 5 | Dial vertical, Pendant up, | 14 | 8 | 8 | 12 |
| 6 | " " right, | 2 | 2 | | |
| 7 | " " left, | 2 | 2 | | |
| 8 | Dial down, | 2 | | | |
| 9 | " up, | 8 | | | |
| | Total No. days, | 42 | 22 | 18 | 12 |

Table showing the number of watches received, and certificates issued, during the year ending May 31, 1883.

| Entered for | | Of which |
|---|---|---|
| Class I. Certificates | 37 | 8 received certificates Class I. |
| " II. " | 5 | 1 " " " II. |
| " III. " | 3 | 1 " " " III. |
| " IV. " | 5 | 4 " " " IV. |
| Total number received | 50 | 9 remain on hand and 27 were returned to their senders as not fulfilling the necessary conditions* for obtaining any certificate. |

* *Conditions of Issuing Certificates.*—No certificate of the classes I., II., III., IV., A, will be issued in the following cases:

1. When the variation of rate with the dial vertical and pendant up in classes I., II., III., and in the positions indicated in classes A and IV., exceeds $2^{s}.0$ from one day to the following day.
2. When the variation of rate between the positions of "Dial up" and "Dial vertical" exceeds $10^{s}.0$.
3. When the variation for $1°$ F. exceeds $0^{s}.3$ between the ordinary temperature and the oven.
4. When the rate is greater than $10^{s}.0$ per day in any position.

No certificate in the classes B or C will be issued in the following cases:

5. When the variation of rate from one day to the following day exceeds $1^{s}.0$, except there be a barometric variation as great as 0.7 inches.
6. When the variation for $2°$ F. exceeds $0^{s}.3$.

In the cases where no certificate is issued the movement will be returned to the maker with a statement of its performance.

The following tables give the individual timepieces receiving certificates during the year.

**TABLE NO. I.—WATCH MOVEMENTS OBSERVED FOR 42 DAYS, IN FIVE POSITIONS, AND IN THE OVEN AND REFRIGERATOR, AND WHICH RECEIVED CLASS I. CERTIFICATES.**

| Rank. | Maker's Number. | Name engraved on the face of the Watch. | Escapement. | Spring. | Mean daily rate. | Mean daily variation. | Variation for 1° Fahr. | Diff. bet. Pendant up and Dial up. | Diff. Pend't up and Pend't right. | Diff. Pend't up and Pend't left. | Diff. Dial up and Dial down. | Diff. bet. extremes of rate. | Mark computed for Daily Variation. | Mark computed for Position. | Mark computed for Temperature. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 1 | 263137 | Vacheron & Constantin. | Anchor. | Breguet. | −0.38 | 0.40 | +0.06 | −1.94 | −0.49 | +1.36 | +1.40 | 4.5 | 32 | 37 | 16 | 85 |
| 2 | 999995 | American Watch Co. | Anchor. | Breguet. | −0.87 | 0.44 | +0.01 | +1.96 | −0.27 | +4.63 | +2.32 | 5.7 | 31 | 33 | 19 | 83 |
| 3 | 1436 | Johnson. | Chronometer. | Cylindrical. | +0.74 | 0.36 | +0.07 | +5.56 | +1.52 | +4.01 | −1.44 | 8.9 | 33 | 33 | 15 | 81 |
| 4 | 263136 | Vacheron & Constantin. | Anchor. | Breguet. | +4.36 | 0.65 | −0.05 | −0.04 | +2.53 | +4.33 | +0.02 | 7.0 | 27 | 33 | 17 | 77 |
| 5 | 1583692 | American Watch Co. | Anchor. | Flat. | −2.19 | 0.40 | −0.05 | +5.76 | −2.22 | −0.25 | −13.55 | 14.7 | 32 | 27 | 17 | 76 |
| 6 | 871104 | American Watch Co. | Anchor. | Breguet. | −4.35 | 0.62 | +0.13 | −2.48 | +2.16 | −0.06 | +3.47 | 7.3 | 28 | 35 | 11 | 74 |
| 7 | 13533 | J. Jürgensen. | Anchor. | Breguet. | +2.18 | 0.81 | +0.08 | +0.70 | −4.20 | +2.40 | +0.80 | 8.1 | 24 | 33 | 15 | 72 |
| 8 | 6049 | Schoof. | Lever.* | Breguet. | −0.06 | 0.63 | −0.19 | +0.95 | +3.96 | −4.71 | −3.34 | 11.0 | 27 | 29 | 7 | 63 |

* Resilient attachment.

TABLE NO. II.—WATCH MOVEMENTS OBSERVED FOR THREE WEEKS, IN FOUR POSITIONS, AND IN OVEN AND REFRIGERATOR, AND WHICH RECEIVED CLASS II. CERTIFICATES.

| Rank. | Maker's Numbers. | Name engraved on the face of the Watch. | Escapement. | Spring. | Mean daily rate. | Mean daily variation. | Variation for 1° Fahr. | Difference between Pendant up and Dial up. | Difference between Pendant up and Pendant right. | Difference between Pendant up and Pendant left. | Difference between extremes of rate. | Mark computed for Daily variation. | Mark computed for Position. | Mark computed for Temperature. | Total.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | | | | | s. | s. | s. | s. | s. | s. | s. | | | | |
| | 6331 | Mermod, Jaccard & Co. | Anchor. | Breguet. | +3.25 | 1.09 | 0.05 | −6.61 | −6.67 | −6.92 | 13.4 | 18 | 30 | 17 | 65 |

TABLE NO. III.—WATCH MOVEMENTS OBSERVED FOR NINETEEN DAYS, IN TWO POSITIONS, AND IN THE OVEN AND REFRIGERATOR, AND WHICH RECEIVED CLASS III. CERTIFICATES.

| Rank. | Maker's Number. | Maker's Name. | Escapement. | Spring. | Mean daily rate. | Mean variation. | Variation for 1° Fahr. | Diff. bet. Pendant up and Dial up. | Diff. bet. extremes of rate. | Mark computed for Daily variation. | Mark computed for Position. | Mark computed for Temperature. | Total.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | s. | s. | s. | s. | s. | | | | |
| | 47141 N | E. Howard & Co. | Anchor. | Flat. | −0.74 | −0.52 | −0.10 | +2.35 | 5.8 | 30 | 35 | 13 | 78 |

* In order to assign to the watches sent to us for certification a certain order of merit in this report, they have been marked upon three qualities, and that watch receiving the highest sum of marks in its class has been placed first in the accompanying tables. The three qualities and the method of computing the marks assigned were:—

1°. The general performance as shown by the mean daily variation of rate, computed by subtracting such day's rate from the rate on the day following, and dividing the numerical sum of these daily variations by the number of days, but omitting the daily variations when a change of position occurred. The mark for a mean daily variation exceeding $2^s.0$ is taken as 0, and the mark for a watch having no variation would be the greatest possible. We have assumed the general performance to be equal in value to the adjustment for position, and we assume the maximum mark to be 40.

The mark for any particular watch may be computed by the formula

$$\frac{2^s.00 \text{ the mean daily variation}}{0.05} = \text{the mark for daily variation.}$$

2°. The adjustment for position, as shown by the mean of the deviations of the rates in different positions from the mean rate during the whole trial. With the assumption that this is of equal importance to (1) we have assumed the maximum mark to be 40.

The mark to be assigned to any watch has been computed from the formula

$$\frac{10^s - \text{mean position variation}}{0^s.25} = \text{the mark for position variation.}$$

This is based upon the consideration that the greatest rate in any position cannot exceed 10 seconds.

3°. The adjustment for compensation in temperature has been assumed to be of half the value of the adjustments necessary for a maximum mark in 1° and 2°, and therefore receives the maximum of 20. The mark to be assigned to any watch for this adjustment has been computed from the formula

$$\frac{0^s.30 - \text{variation for } 1^\circ \text{ Fahr.}}{0^s.015} = \text{the mark for temperature compensation.}$$

This is based upon the consideration that the maximum limit of temperature variation is fixed at $0^s.30$ for 1° Fahr.

In the following tables, I, II, III, are given the results of the rating of watches which received certificates of the classes I., II., III., during the year.

The last four columns give the numbers computed for the relative rank of the watch as compared with the others sent in to the observatory and which received certificates of the same class.

In addition to the above watch movements there was entered by H. H. Heinrichs, New York, one of his patent auxiliary compensation balance marine chronometers, for a certificate of class A. The rate of this chronometer for the last two months of its trial was as follows:—

TABLE NO. IV.—MARINE CHRONOMETER, "H. H. HEINRICHS," NO. 4," OBSERVED FOR TWO MONTHS IN ONE POSITION AND IN THE OVEN AND REFRIGERATOR, AND WHICH RECEIVED A CLASS A CERTIFICATE.

| Date. | Rate. | Variation. | Temp. | Date. | Rate. | Variation. | Temp. |
|---|---|---|---|---|---|---|---|
| 1883. | s. | s. | ° | 1883. | s. | s. | ° |
| Feb. 23 | +0.7 | 0.9 | 58 | March 26 | −0.2 | 0.2 | 56 |
| 24 | 0.0 | 0.7 | 57 | 27 | +0.4 | 0.6 | 56 |
| 25 | +0.2 | 0.2 | 56 | 28 | +0.2 | 0.2 | 56 |
| 26 | −0.4 | 0.6 | 57 | 29 | −0.3 | 0.5 | 56 |
| 27 | −0.3 | 0.1 | 60 | 30 | −0.3 | 0.0 | 55 |
| 28 | +0.5 | 0.8 | 59 | 31 | +0.2 | 0.5 | 56 |
| March 1 | −0.1 | 0.6 | 59 | April 1 | +0.6 | 0.4 | 54 |
| 2 | −0.1 | 0.0 | 58 | 2 | −0.9 | 1.5 | 55 |
| 3 | −0.1 | 0.0 | 57 | 3 | −0.5 | 0.4 | 57 |
| 4 | −0.1 | 0.0 | 57 | 4 | +0.4 | 0.9 | 56 |
| 5 | −0.5 | 0.4 | 56 | 5 | −0.1 | 0.5 | 56 |
| 6 | −0.1 | 0.4 | 56 | 6 | 0.0 | 0.1 | 59 |
| 7 | +0.3 | 0.4 | 55 | 7 | +0.5 | 0.5 | 60 |
| 8 | −0.1 | 0.4 | 55 | 8 | +0.3 | 0.2 | 60 |
| 9 | +0.3 | 0.4 | 55 | 9 | +0.9 | 0.6 | 59 |
| 10 | +0.1 | 0.2 | 54 | 10 | +0.4 | 0.5 | 59 |
| 11 | 0.0 | 0.1 | 53 | 11 | +0.5 | 0.1 | 60 |
| 12 | −0.3 | 0.3 | 53 | 12 | +0.1 | 0.4 | 60 |
| 13 | −0.2 | 0.1 | 53 | 13 | +0.6 | 0.5 | 61 |
| 14 | +0.3 | 0.5 | 55 | 14 | +0.1 | 0.5 | 61 |
| 15 | +0.2 | 0.1 | 56 | 15 | +0.4 | 0.3 | 62 |
| 16 | −0.2 | 0.4 | 57 | 16 | +0.3 | 0.1 | 61 |
| 17 | 0.0 | 0.2 | 56 | 17 | +0.7 | 0.4 | 61 |
| 18 | +0.1 | 0.1 | 55 | 18 | +0.1 | 0.6 | 62 |
| 19 | +0.1 | 0.0 | 55 | 19 | +0.2 | 0.1 | 62 |
| 20 | −0.2 | 0.3 | 55 | 20 | +0.3 | 0.1 | 63 |
| 21 | −0.1 | 0.1 | 56 | 21 | +0.1 | 0.2 | 62 |
| 22 | +0.4 | 0.5 | 56 | 22 | +0.1 | 0.0 | 62 |
| 23 | +0.1 | 0.3 | 55 | 23 | +0.2 | 0.1 | 60 |
| 24 | 0.0 | 0.1 | 55 | 24 | +0.7 | Oven | 87 |
| 25 | 0.0 | 0.0 | 56 | 25 | −0.7 | Refrigerator | 42 |

The following table gives a resumé of the watches certified during the three years of this service :—

| | 1880–81. | 1881–82. | 1882–83. |
|---|---|---|---|
| Percentage of watch movements receiving certificates of any kind, | 45 | 38 | 28 |
| Number receiving Class I Certificates, | 22 | 12 | 8 |
| Average mark of Class I Certificates, | 68.8 | 68.6 | 76.4 |
| Highest mark received during the year, | 83 | 82 | 85 |
| Maker's name, | Am. Watch Company, Waltham. | Barrand & Lunds, London. | Constantin & Vacheron, Geneva. |

It will be observed that the average mark for the past year is considerably higher than for the two preceding years.

During the year the chronographs, clocks, safes and other apparatus used in this service have been transferred from the room loaned us by the Sheffield Scientific School, and the rented quarters in Orange street, to the new observatory building. The clocks are now in a specially constructed room, and the watch movements sent for trial are kept in proper fire-proof accommodations until returned. The full description of the new arrangement of clocks, safes, chronographs and electric apparatus properly belongs to the memoirs of the observatory, and will appear in that place in due season.

It has been suggested to us, from various quarters, that a school of Horology is needed in this country, similar in its scope and equipment to those abroad. It has been further urged that certain courses of the Scientific School could be utilized for the instruction of technical students in this connection, and some friends of such an enterprise are willing to furnish a part of the necessary plant. Before such an undertaking can be seriously considered by the proper authorities, it will be necessary that the endowment for at least two of the chairs of instruction should be provided for, and a sum of money for the incidental expenses of such a school be furnished by the friends of such an enterprise.

A school of this character is no doubt needed by one of our leading industries, and it will not be difficult, should the financial support be furnished, to establish a course of study and manipulation which should lead to a certificate of training and ability in this direction.

### THE STATE TIME SERVICE.

The Observatory Time Signals, in accordance with the contract with the State of Connecticut referred to in my last report, have been regularly transmitted to the Railroads of the State. To encourage the public confidence in the accuracy of these telegraphic time signals, the

custom has been established of furnishing, as a news item to all the newspapers in the State, the mean monthly errors of these signals at 12 o'clock noon. The following table gives the number of days on which observations took place and the arithmetical means of the daily errors of the time signals, for the respective months:

| Month. | | Nights Observations. | Monthly Means of the errors of the Daily Time Signals. |
|---|---|---|---|
| 1882 | June, | 22 | $0^s.11$ |
| | July, | 24 | 0.15 |
| | August, | 25 | 0.26 |
| | September, | 14 | 0.48 |
| | October, | 16 | 0.17 |
| | November, | 22 | 0.20 |
| | December, | 22 | 0.55 |
| 1883 | January, | 12 | 0.37 |
| | February, | 13 | 0.71 |
| | March, | 22 | 1.31 |
| | April, | 19 | 1.68 |
| | May, | 23 | 0.66 |

The comparatively large monthly mean errors from February to May are owing to changes then made in the clocks and were in part incident to the removal of the observatory.

Three independent telegraph lines of covered wire have been built from the new observatory to the main office of the Southern New England Telephone Company, by the Standard Time Company. One of these lines is used for the distribution of the regular two second continuous time signals to the Jewellers and the Railroads, the second line is used to send an hourly current for synchronizing the clocks erected in different offices in the city by the Standard Time Company, and the third line is used for telephonic purposes.

The Hartford Time Ball continues to be dropped at noon at Hartford by our noon railroad signal, and the New York, New Haven and Hartford Railroad has a synchronized clock at Hartford, thirty-eight miles by the telegraph route from the observatory, which has been synchronized by our noon signal for several months with entire satisfaction. The whole question of railroad time

will be much simplified after the general introduction of clocks which are set at the same instant by telegraph throughout systems of railroad telegraph lines.

Through the courtesy of the Standard Time Company and the Southern New England Telephone Company, we were enabled to place ourselves in direct telegraphic and telephonic communication with the "Transit of Venus" expedition which was stationed at Hartford during October, November and December. We furnished them with our time signals twice per day during this interval, and the service we rendered them has been appropriately recognized by the "Commission für die Beobachtung des Venus-Durchgangs," through its secretary, Professor Auwers.

## THE THERMOMETRIC BUREAU.

The number of thermometers received for examination continues to increase. There has been a total of 5295 certificates issued, as follows:

21 with mercurial standards up to 100° C.
31 with mercurial standards up to 275° C.
12 with Yale Observatory standard thermometers.
1 with minimum meteorological alcohol thermometer.
51 with maximum meteorological mercurial thermometers.
39 with ordinary meteorological mercurial thermometers.
5140 with physicians' clinical mercurial thermometers.

Compared with the two preceding years' work the figures are as follows:

| | 1880–81 | 1881–82 | 1882–83 |
|---|---|---|---|
| Physicians' thermometers examined, | 1667 | 3811 | 5140 |
| Other thermometers examined, | 290 | 741 | 155 |
| Total, | 1957 | 4552 | 5295 |

The decrease in the number of thermometers other than Physicians, is owing to the fact that the greater portion of the thermometers for the Signal Service of the Army are now compared at their Washington office, with the apparatus and standards furnished by us to them for this purpose. There have been 300 thermometers received for sealing, to be examined in one year or later.

The percentage of breakage continues about the same. During the past year 30 were broken owing to bad packing and careless handling before reaching the observatory, and 7, or about 1 in 800, were broken during examination at the observatory. On March 1st a revised scale of observatory fees* was issued with the object of encour-

***SCALE OF CHARGES FOR THERMOMETER CERTIFICATE**
**Revised March 1, 1883.**

| Comparison Number. | Kind of Thermometer. | At what points Certificates of Comparison are furnished in Fahrenheit or corresponding Centigrade degrees. | Limit within which the Observatory comparison is accurate. | Observatory Fee for each Thermometer |
|---|---|---|---|---|
| 1 | Clinical or Physicians', | 90°, 95°, 100°, 105°, 110°, | ⅛° or 1/10° | $0. |
| 2 | Ordinary Meteorological, Mercurial or Spirit, | 32°, 52°, 72", 92°, | 1/10° | . |
| 3 | The same, | 2°, 32°, 52°, 72°, 92°, 112°, | 1/10° | 0. |
| 4 | The same, | Every 10° from 0° to 100°, | 1/10° | 1. |
| 5 | Ordinary Meteorological, Maximum or Minimum, | 32°, 52°, 72°, 92°, | 1/10° | . |
| 6 | The same, | 2°, 32°, 52°, 72°, 92°, 112°, | 1/10° | 1. |
| 7 | The same, | Every 10° from 0° to 100°, | 1/10° | 1. |
| | Standards, | Every 20° from 32° to 212°, | 1/10° | 2. |
| 8 | The same, | Every 10° from 32° to 212°, | 1/10° | 3. |
| 9 | The same, | Every 5° from 0° to 215°, and depressed freezing point | 1/10° | 5. |
| 10 | Chemical, | Every 20° from 32° to 212°, | ⅛° | 1. |
| 11 | The same, | Every 20° from 32° to 332°, | ⅛° above 300° | 3. |
| 12 | The same, | Every 20° from 32° to 632°, | ⅛° above 300° | †5. |
| 13 | The same, | Every 20° from 32° to 212°, | 1/10° | 2. |
| 14<br>15 | The same, | Every 20° from 32° to 632°, by calibration above 212°, | ½° | 2. |
| 16 | Oil Testing Thermometers, | Every 5° from 80° to 150°, | ⅛° | 1. |
| 17 | The same, | Every 5° from 80° to 150°, | 1/10° | 2. |
| 18 | The same, | Every 5° from 80° to 250°, | 1/10° | 4. |
| 19 | Thermometers of precision, | 32° point, boiling point and depressed freezing point determination, | 1/50° | 2. |
| 20 | The same, | Each additional point, | 1/50° | . |
| 21 | Boiling point standards, | Every 2° from 190° to 214°, | 1/50° | 2. |

† This comparison differs from 14 in determining certain points between 21 and 632° by direct comparison.

Quantity discount allowed when six or more thermometers of the same class a sent at the same time:

| | | | |
|---|---|---|---|
| On ½ dozen, | 20 per cent. | On 6 dozen, | 40 per cent. |
| On 1 " | 25 " | On 12 " | 45 " |
| On 2 " | 30 " | On 24 " | 50 " |
| On 4 " | 35 " | | |

aging the sending of thermometers in large lots. This result has been attained with the advantage of giving us more time for researches in Thermometry. Mr. Sherman has been conducting, researches in regard to the Air Thermometer, and in connection with his regular work, in regard to methods for comparing at temperatures above 100° C. This latter problem is one of peculiar importance to us, because in many of the arts there are now needed considerable numbers of thermometers fairly accurate to the boiling point of mercury.

We have added to this department, during the year, the following pieces of apparatus:

1. Boiling point Standard Thermometer "R. Fuess 32." Graduated from $-1°.50$ to $+1°.00$ and from $86°.25$ to $+100°.50$ C. $1° = 9.40^{mm}$. Smallest graduation is $0°.05$ C. and $270^{mm}$ extreme length. Cylindrical bulb $25 \times 7.5^{mm}$ and porcelain scale.
2. Normal Thermometer "R. Fuess 133." Graduated from $-6°.9$ to $+101°.0$ C. $1° = 3.72^{mm}$. Smallest graduation is $0°.10$ C. and $563^{mm}$ extreme length. Cylindrical bulb $20 \times 6^{mm}$ and porcelain scale. (This thermometer is to replace "Fuess 89," which was broken).
3. Water Comparator—Fuess form—for comparing short standards.
4. Linear Comparator—for calibrating thermometers and comparing measures—by Zeiss, of Jena. Fitted with two microscope stands (Zeiss 6048 and Zeiss 6023), with Zeiss objectives A, Beck objectives 4 inch, and Zeiss micrometer eye-pieces to 2.

Mr. Sherman has investigated the methods for the examination of hydrometers, at the instance of the State Board of Health of New York. Seven instruments of this kind were examined. Hereafter we can perform this service without difficulty for any such number as are likely to be sent to us.

Mr. R. W. Willson has had the care of moving the horological bureau and its work during the year, and Mr. O. T. Sherman has had a similar responsibility for the thermometric bureau. These departments have been strengthened by the appointment by the corporation of Robert Brown, Jr., to the secretary of the observatory,

in which capacity he has assumed the care of the observatory property, accounts, and the issuance of certificates of all classes.

Respectfully submitted,

LEONARD WALDO,

*Astronomer in Charge of the Bureau.*

To Prof. H. A. NEWTON,

*Director of the Observatory in Yale College.*

REPORT FOR THE YEAR 1883–4, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY TO THE PRESIDENT AND FELLOWS OF YALE COLLEGE.

# Observatory in Yale College.

## BOARD OF MANAGERS.



## OFFICERS.

Robert Brown, Jr., M.A., *Secretary.*
Leonard Waldo, S.D., *Astronomer in charge of the Horological Bureau.*
Orray T. Sherman, B.A., *Assistant Astronomer.*
William L. Elkin, Ph.D., *Astronomer in charge of the Heliometer.*

# REPORT.

ENTLEMEN :

The Horological and Thermometric Bureaus of the Observ-ory have been carried on during the past year under Dr. 'aldo's direction. For the details of the work we refer you his Report to us, which is herewith transmitted to you.

Mr. Wilson had charge of the time-service until October, hen, to our serious loss, he withdrew from the Observatory, d went to Europe. Since October, Dr. Waldo has done this ork. The photographs taken by Mr. Willson during the ransit of Venus have been placed in the hands of the Tran-Commission at Washington for measurement.

In the Thermometric Bureau, Mr. Sherman has made the mparisons of thermometers throughout the year. For an count of his other scientific work we refer to his report rewith submitted.

Mr. Brown has prepared and has issued the certificates for struments verified in the Bureaus, has kept the financial counts of the Bureaus, and has superintended the work on e grounds of the Observatory reservation. Already these ounds show the results of his good taste and superintend-ce, and in coming years these results will be still more anifest.

Prof. Kershner has completed his computation for the termination of the scale values of the Heliometer from the servations of the stars $\eta$, 17 and 27 in the Pleiades, from ose of the Cygnus-bogen, and from transits of $\alpha$ Tauri. The eliometer observations of the Transit of Venus, made by r. Waldo and Prof. Kershner, have been reduced (by using e resulting scale value), so far as the equations of condition.

Prof. Newton continued in the discharge of his duties as irector until the acceptance of his resignation, May 8th.

The importance of having an observer whose whole time uld be given to the Heliometer, and thus of making

a beginning in earnest of that kind of work for which Mr. Winchester gave to the Observatory his generous donation, has been long felt by us. We had a Heliometer of unsurpassed excellence, and it was due to the College, to the public, and to science, that the best possible use be made of it. This could be done only by an observer who had no other demands upon his time. The opportunity occurred in the later months of 1883, of securing the services of Dr. W. L. Elkin. He had given special study to the Heliometer at Strasburg, and for two years had had very valuable experience in the use of it in connection with and under the guidance of Dr. Gill, the Astronomer Royal at the Cape of Good Hope. To improve this opportunity a subscription was made by ten officers and friends of the Observatory of one hundred dollars each per year for three years, and Dr. Elkin was appointed by you for that period Astronomer in the Observatory in charge of the Heliometer. He entered upon his duties in January. His report of work done is herewith presented.

The following are the ten subscribers referred to:

| | | |
|---|---|---|
| Elias Loomis, | Class of | 1830. |
| Richard S. Fellowes, | " | 1832 (since deceased). |
| Henry C. Kingsley, | " | 1834. |
| Morris W. Lyon, | " | 1846. |
| Hubert A. Newton, | " | 1850. |
| Robert Brown, Jr., | " | 1857. |
| Henry F. Dimock, | " | 1863. |
| Levi C. Wade, | " | 1866. |
| George T. Bliss, | " | 1873. |
| Edward W. Southworth, | " | 1875. |

The grading of Caner Street is now nearly completed upon our portion of the street, and the lots fronting upon it are among the most attractive for residences in the city. The expense has been considerable, but a large fraction of it has been saved to the Observatory by reason of the demand for the material excavated.

The addition of the President of the College to the Board of Managers by your vote, May 18th, will, it is believed, result in good both to the Observatory and to the College. We think that he should have been a member of the Board from the beginning.

For additions to the Library of the Observatory we are ndebted to the following persons:

The Director of the Observatory at Cambridge, Mass.
Washington.
Oxford (Radcliffe).
Dun Echt.
Neuchatel.
Ekaterinburgh.
Moscow.
Tacubaya.
Rio de Janeiro.
Secretaria de Fomento de la Republica Mexicana.
Chief Signal Officer, U. S. Army.
Superintendent of the American Ephemeris.
Lords Commissioners of the Admiralty.
Engineer in charge of the U. S. Geographical Surveys.
Canadian Institute, Toronto.
Philosophical Society, Washington.
Jewelers' Journal, Chicago.
H. Carrington Bolton.
Th. Bredichin.
J. D. and E. S. Dana.
Mrs. Henry Draper.
William D. Ely.
Edmund A. Engler.
A. Hirsch.
Victor Kremser.
E. K. Moore.
E. C. Pickering.

Respectfully submitted to the President and Fellows of Yale College.

By order of the Board of Managers,

H. A. NEWTON,
*Secretary.*

Yale College, June 19, 1884.

# REPORT OF DR. WALDO.

To the Board of Managers:

Gentlemen—The present report refers to the work in the Horological and Thermometric Bureaus during the year ending May 31, 1884.

## THE HOROLOGICAL BUREAU.

The methods of comparing time-pieces, and in general of conducting the work of the Bureau, continued the same as in the preceding year. The number of watches received from the makers since the commencement of the work of the Bureau is as follows:

| | |
|---|---|
| 1880–81 | 219 |
| 1881–82 | 53 |
| 1882–83 | 41 |
| 1883–84 | 87 |

It will be seen from the subsequent analysis of their performance that there has been a marked increase in the excellence of the movements submitted to our trials, which, so far as can be observed, is a direct result of the interest our work in this department has excited.

The duration of the trials and the positions during their rating of the watches submitted during the past year, are shown in the following table:

| Test No. | Position. | Approximate Temperature. | Number of days trial for Class Certificates. I. | II. | III. | IV. |
|---|---|---|---|---|---|---|
| 1 | Dial vertical, Pendant up | 60° to 70° F. | 7 | 8 | 8 | 12 |
| 2 | Dial vertical, Pendant right | 60° to 70° F. | 2 | 2 | | |
| 3 | Dial vertical, Pendant left | 60° to 70° F. | 2 | 2 | | |
| 4 | Dial horizontal, Dial down | 60° to 70° F. | 2 | | | |
| 5 | Dial horizontal, Dial up | 60° to 70° F. | 10 | 8 | 8 | or 12 |
| 6 | Dial horizontal, Dial up | 34° to 38° | 1 | 1 | 1 | |
| 7 | Dial horizontal, Dial up | 95° to 100° | 1 | 1 | 1 | |
| 8 | Dial horizontal, Dial up | 60° to 70° | 10 | | | |
| 9 | Dial vertical, Pendant up | 60° to 70° | 7 | | | |
| | Total number of days | | 42 | 22 | 18 | 12 |

The conditions excluding watches from certification continue as follows:

1. When the variation of rate with the dial vertical and pendant up in classes I., II., III., and in the positions indicated in class IV., exceeds $2^s.0$ from one day to the following day.

2. When the variation of rate between the positions of "Dial up" and "Dial vertical" exceeds $10^s.0$

3. When the variation for $1^\circ$ F. exceeds $0^s.3$ between the ordinary temperature and the oven.

4. When the rate is greater than $10^s.0$ per day in any position.

The number of watches received, and certificates issued, during the year ending May 31, 1884, are as follows:

| Entered for— | | Of which— |
|---|---|---|
| Class I. certificates | 57 | 42 received certificates Class I. |
| Class II. certificates | 7 | 5 received certificates Class II. |
| Class III. certificates | 3 | 3 received certificates Class III. |
| Class IV. certificates | | 19 received rate records. |
| Special rate records | 20 | None remain on hand, and 18 were returned to their senders as not fulfilling the necessary conditions for obtaining any certificate or rate record. |
| Total number received | 87 | |

The following tables give abstracts of the performance of the individual watches receiving certificates during the year:

TABLE No. 1.—WATCH

| Rank. | Maker's Name. | Maker's Number. | Adjusted b |
|---|---|---|---|
| 1 | American Watch Co., Waltham, Mass., | 1560072 | American Watch |
| 2 | Paul Breton, Geneva, | 12187 | H. H. Heinrich, |
| 3 | Karl Zimmerman, Liverpool, | 15690 | H. H. Heinrich, |
| 4 | Karl Zimmerman, Liverpool, | 15682 | H. H. Heinrich, |
| 5 | J. Jurgensen, Copenhagen, | 10852 | M. Cooper, |
| 6 | American Watch Co., Waltham, Mass., | 1561793 | American Watch |
| 7 | American Watch Co., Waltham, Mass., | 1561690 | American Watch |
| 8 | Albert H. Potter & Co., Geneva, | 609 | Albert H. Potter |
| 9 | Karl Zimmerman, Liverpool, | 15620 | Geo. E. Wilkins, |
| 10 | Paul Breton, Geneva, | 12319 | H. H. Heinrich, |
| 11 | Edouard Richard, Locle, | 42940 | F. G. Crandale, N |
| 12 | American Watch Co., Waltham, Mass., | 1561695 | American Watch |
| 13 | American Watch Co., Waltham, Mass., | 1561687 | American Watch |
| 14 | W. G. Schoof, London, | 6052 | Geo. E. Wilkins, |
| 15 | Paul Breton, Geneva, | 12078 | H. H. Heinrich, |
| 16 | American Watch Co., Waltham, Mass., | 999930 | American Watch |
| 17 | Paul Breton, Geneva, | 12178 | H. H. Heinrich, |
| 18 | Albert H. Potter & Co., Geneva, | 612 | Albert H. Potter |
| 19 | Paul Breton, Geneva, | 12406 | H. H. Heinrich, |
| 20 | Edouard Richard, Locle, | 42941 | F. G. Crandale, N |
| 21 | Paul Breton, Geneva, | 12180 | H. H. Heinrich, |
| 22 | Karl Zimmerman, Liverpool, | 435 | Geo. E. Wilkins, |
| 23 | Edouard Richard, Locle, | 16966 | F. G. Crandale, N |
| 24 | Edouard Richard, Locle, | 16379 | F. G. Crandale, N |
| 25 | Karl Zimmerman, Liverpool, | 15698 | Geo. E. Wilkins, |
| 26 | American Watch Co., Waltham, Mass., | 871189 | American Watch |
| 27 | Karl Zimmerman, Liverpool, | 357 | H. H. Heinrich, |
| 28 | American Watch Co., Waltham, Mass., | 1427902 | American Watch |
| 29 | American Watch Co., Waltham, Mass., | 871181 | American Watch |
| 30 | Paul Breton, Geneva, | 12410 | H. H. Heinrich, |
| 31 | Paul Breton, Geneva, | 12318 | H. H. Heinrich, |
| 32 | American Watch Co., Waltham, Mass., | 1427914 | American Watch |
| 33 | Paul Breton, Geneva, | 12182 | H. H. Heinrich, |
| 34 | Edouard Richard, Locle, | 42950 | F. G. Crandale, N |
| 35 | Edouard Richard, Locle, | 42951 | F. G. Crandale, N |
| 36 | Paul Breton, Geneva, | 12179 | H. H. Heinrich, |
| 37 | Paul Breton, Geneva, | 12408 | H. H. Heinrich, |
| 38 | Paul Breton, Geneva, | 12317 | H. H. Heinrich, |
| 39 | J. Jurgensen, Copenhagen, | 14026 | H. H. Heinrich, |
| 40 | Edouard Richard, Locle, | 43008 | F. G. Crandale, N |
| 41 | Edouard Richard, Locle, | 43001 | F. G. Crandale, N |
| 42 | Edouard Richard, Locle, | 42999 | F. G. Crandale, N |

ENTS OBSERVED FOR 42 DAYS, IN FIVE POSITIONS, AN

| Escapement. | Spring. | Mean daily rate. | Mean daily variation. | Variation for 1° Fahr. | Diff. before and after oven and refrigerator | D Pe a |
|---|---|---|---|---|---|---|
| .ever, | Flat, | +3s.27 | 0s.38 | 0s.00 | −0s.59 | |
| .ever, | Breguet, | −0.47 | 0.35 | +0.04 | −0.65 | |
| .ever, Fusee, | Breguet, | +0.64 | 0.47 | +0.03 | −0.45 | |
| .ever,* | Breguet, | −0.27 | 0.49 | −0.012 | +0.28 | |
| .ever, | Breguet, | −2.64 | 0.44 | −0.03 | −0.47 | |
| .ever, | Flat, | +1.80 | 0.52 | −0.03 | −0.77 | |
| .ever, | Flat, | +2.60 | 0.60 | +0.006 | +2.63 | |
| .nchor, | Breguet, | −0.29 | 0.41 | +0.10 | −0.08 | |
| .ever, | Breguet, | −3.44 | 0.52 | −0.03 | +0.30 | |
| .ever, | Breguet, | +2.07 | 0.49 | +0.04 | −0.24 | |
| .ever, | Breguet, | −2.25 | 0.74 | +0.05 | +0.49 | |
| .ever, | Flat, | −1.06 | 0.40 | +0.073 | −1.16 | |
| .ever, | Flat, | −0.44 | 0.40 | −0.094 | −0.17 | |
| choof's Res., | Breguet, | +0.85 | 0.74 | +0.004 | +0.42 | |
| .ever, | Breguet, | −0.68 | 0.60 | −0.06 | −1.06 | |
| .ever, | Breguet, | −0.05 | 0.53 | −0.023 | +0.10 | |
| .ever, | Breguet, | −1.37 | 0.72 | −0.08 | −0.65 | |
| .nchor, | Breguet, | +0.73 | 0.49 | −0.09 | −0.35 | |
| .ever, | Breguet, | ——† | 0.62 | −0.01 | −0.16 | |
| .ever, | Breguet, | −6.21 | 0.84 | +0.07 | −0.29 | |
| .ever, | Breguet, | −6.76 | 0.76 | −0.04 | +1.28 | |
| .ever, | Breguet, | +2.60 | 0.78 | −0.12 | +0.03 | |
| .ever, | Breguet, | −2.71 | 0.56 | +0.14 | +1.11 | |
| .ever, | Breguet, | +5.04 | 0.89 | +0.09 | −0.64 | |
| .ever, | Breguet, | +0.08 | 0.69 | +0.003 | −0.04 | |
| .ever, | Breguet, | +1.04 | 0.41 | −0.15 | +0.26 | |
| .ever, | Breguet, | −0.84 | 0.64 | +0.126 | +0.83 | |
| .ever, | Flat, | −3.20 | 0.89 | +0.042 | −1.47 | |
| .ever, | Breguet, | −0.39 | 0.82 | −0.01 | −1.24 | |
| .ever, | Breguet. | −0.66 | 0.54 | +0.09 | +0.32 | |
| .ever, | Breguet, | −4.45 | 0.71 | +0.033 | −0.34 | |
| .ever, | Breguet, | +0.44 | 0.79 | +0.09 | −0.87 | |
| .ever, | Breguet, | −4.79 | 0.77 | −0.07 | +1.16 | |
| .ever, | Breguet, | −4.05 | 0.72 | −0.11 | +0.46 | |
| .ever, | Breguet, | +5.17 | 0.69 | +0.09 | +0.46 | |
| .ever, | Breguet, | −1.92 | 0.82 | +0.06 | −0.18 | |
| .ever, | Breguet, | −2.90 | 0.59 | +0.13 | +0.20 | |
| .ever, | Breguet, | +0.39 | 0.74 | +0.05 | +5.64 | |
| .ever, | Breguet, | ——† | 0.76 | +0.09 | +0.30 | |
| .ever, | Breguet, | +1.48 | 0.80 | −0.24 | −0.78 | |
| .ever, | Breguet, | −1.64 | 0.79 | −0.18 | −1.05 | |
| .ever, | Breguet, | +3.81 | 0.92 | +0.22 | −3.03 | |

* Heinrich's auxiliary compensation balance.

here have been received four marine chronometers, all of ch are of the highest class of workmanship and are all vided with auxiliary compensations.

he performance of these chronometers under varying con- ons of temperature is shown in the following tables:

ı OF THE WEEKLY RATES OF FOUR MEAN TIME CHRONOMETERS RATED DURING MARCH, APRIL AND MAY, 1884.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| s name | H.H.Heinrich. | | H.H.Heinrich. | | H.H.Heinrich, | | W. Bröcking, Hamburg. | |
| s number | 6 | | 9 | | 13 | | 988 | |
| d by | The maker. | | The maker. | | The maker. | | The maker. | |
| nent | Chronometer. | | Chronometer. | | Chronometer. | | Chronometer. | |
| | Vertical spiral. | | Vertical spiral. | | Vertical spiral. | | Vertical spiral. | |
| | Heinrich's pat. auxiliary. | | Heinrich's pat. auxiliary. | | Heinrich's pat. auxiliary. | | Auxiliary Compensat'on. | |
| daily rates: | Sum. | Temp. | Sum. | Temp. | Sum. | Temp. | Sum. | Temp. |
| eek | 0ˢ.0* | 67° | + 6ˢ.6* | 36° | −3ˢ.1 | 63°F. | +3ˢ.1 | 60° |
| ek | +3.1 | 36 | + 6.3 | 60 | −4.3* | 38 | +4.1 | 58 |
| ek | −0.2 | 64 | +14.6 | 58 | +2.4 | 66 | +5.2 | 65 |
| eek | +4.0 | 58 | +11.9 | 65 | +3.9 | 36 | +5.7 | 67 |
| eek | +2.3 | 65 | + 9.6 | 66 | +2.9 | 65 | +4.7 | 66 |
| eek | +1.4 | 67 | + 5.8 | 66 | +4.2 | 58 | +4.4 | 67 |
| eek | +0.3 | 65 | +11.1 | 70 | +3.7 | 63 | +4.1 | 67 |
| eek | −1.6 | 68 | | | +6.0 | 66 | +4.3 | 67 |
| eekly variat'n | 1ˢ.5 | | 2ˢ.7 | | 3ˢ.5 | | 0ˢ.4 | |
| d | 374 | | 375 | | 370 | | 376 | |
| d from | H.H.Heinrich, New York. | | H.H.Heinrich, New York. | | H.H.Heinrich, New York. | | The Physical Laboratory of the U. S. Geological Survey. | |

* Four day periods.

ı tower clock, made by and received from the Seth Thomas ck Company, of Thomaston, Conn., with dead beat escape- at, varnished wood rod, steel spring suspension, and an ı cylindrical bob whose diameter and hight are about 135 310 millimeters respectively, was rated during two periods. ween the periods the rate was lessened by removing a ll weight from the pendulum bob. The temperature

ranged between 55° and 77° F. The results are shown in the following table:

| 1st Period, Jan. 3d to Jan. 30th, 1884. | | | 2d Period, Feb. 10th to March 17th, 1884. | | |
|---|---|---|---|---|---|
| No. days. | Mean daily rate. | Variati'n of rate bet. successive intervals. | No. days. | Mean daily rate. | Variati'n of rate bet. successive intervals. |
| | s. | s. | | s. | s. |
| 10 | +5.54 | | 3 | −0.33 | |
| 4 | +5.43 | +0.11 | 4 | −0.32 | −0.01 |
| 3 | +5.45 | −0.02 | 4 | −0.18 | −0.14 |
| 4 | +6.56 | −1.11 | 10 | −0.50 | +0.32 |
| 3 | +6.21 | +0.35 | 4 | −1.12 | +0.62 |
| 4 | +6.28 | −0.07 | 3 | −1.00 | −0.12 |
| | | | 4 | −0.50 | −0.50 |
| | | | 3 | −1.50 | +1.00 |

The following table gives a resumé of the watches certified during the past four years:

| Year | 1880–81. | 1881–82. | 1882–83. | 1883–84. |
|---|---|---|---|---|
| Percentage of watch movements receiving certificates of any kind, excluding watches entered for rate records | 45 | 38 | 28 | 77 |
| Number receiving Class I. certificates | 22 | 12 | 8 | 42 |
| Average mark of Class I. certificates | 68.8 | 68.6 | 76.4 | 74.4 |
| Average mark of the first five watches receiving class I. certificates | 79.4 | 77.0 | 80.4 | 85.8 |
| Highest mark received during the year | 83 | 82 | 85 | 90.4 |
| Makers' name of watch receiving the highest mark during the year | American WatchCo. Waltham. | Barraud & Lunds, London. | Vacheron & Constantin Geneva. | American WatchCo. Waltham. |

In preceding reports the desirability of altering the form of our watch trials has been pointed out. During the past year this subject has been under consideration by the superintendents of the observatories at Geneva, Switzerland, and of Kew, England, and by ourselves, with the result that an inter-

ational system has been agreed upon, by which the trials at eneva, Kew, and Yale will be strictly comparable.

I submit herewith the revised regulations for this Bureau ecessary to carry this international scheme into practical peration so far as we are concerned. The scheme has been operation for some years at the Geneva Observatory, and as announced in May of this year as adopted at the Royal ociety's observatory at Kew.

## EGULATIONS GOVERNING THE ISSUE OF CERTIFICATES OF RATES OF TIMEPIECES, AFTER OCTOBER 1, 1884.

### I.—*Classes of Certificates.*

The following classes of certificates will be issued with mepieces which have been deposited at this observatory for ial:

The certificates will contain a detailed statement of the sults obtained with each particular movement.

In describing the positions of a movement, the term "Dial p" indicates that the plane of the dial is horizontal, and with e engraved side uppermost. "Dial vertical" indicates at the plane of the dial is vertical.

The temperature of the refrigerator is approximately 40° F., at of the oven is approximately 90° F., and the ordinary mperature ranges between 65° and 75° F.

1. Class A includes those certificates issued with pocket ronometers or watches which have been subjected while ting to the following variations of position and temperature:

| Period. | Occurs during the days of the trial. | Position. | Temperature. |
|---|---|---|---|
| First. | 1st to 6th. | Dial Vertical, Pendant up. | Ordinary. |
| Second. | 6th to 11th. | Dial Vertical, Pendant Right. | Ordinary. |
| Third. | 11th to 16th. | Dial Vertical, Pendant Left. | Ordinary. |
| Fourth. | 16th to 22d. | Dial up. | Refrigerator. |
| Fifth. | 22d to 28th. | Dial up. | Ordinary. |
| Sixth. | 28th to 34th. | Dial up. | Oven. |
| Seventh. | 34th to 40th. | Dial down. | Ordinary. |
| Eighth. | 40th to 45th. | Dial Vertical, Pendant up. | Ordinary. |

The trial comprises forty-five days, during which the movement is rated in five positions during periods of five days each, and is exposed to cold, warm, and average temperatures. In order that the movements may assume their new rates under changed conditions, the first day's rating in the 4th, 5th, 6th, and 7th periods are not used in making up the record of a movement's performance.

2. Class B includes those certificates issued with pocket chronometers or watches which have been subjected while rating to the following variations of position and temperature:

| Period. | Occurs during the days of the trial. | Position. | Temperature. |
|---|---|---|---|
| First. | 1st to 15th. | Dial Vertical, Pendant up. | Ordinary. |
| Second. | 15th to 29th. | Dial up. | Ordinary. |
| Third. | 29th to 30th. | Dial up. | Refrigerator. |
| Fourth. | 30th to 31st. | Dial up. | Ordinary. |
| Fifth. | 31st to 32d. | Dial up. | Oven. |

3. Class C includes those certificates issued with pocket chronometers or watches which have been subjected while rating to the following variations of position and temperature.

| Period. | Occurs during the days of the trial. | Position. | Temperature. |
|---|---|---|---|
| First. | 1st to 9th. | Dial Vertical, Pendant up. | Ordinary. |
| Second. | 9th to 17th. | Dial up. | Ordinary. |

Certificates of the classes A, B, and C are issued in two grades. The ordinary certificate is issued when the observed ratings show that an excellence has been attained which is within the limits assigned in the third column of the following table and the certificates have the words "especially good" attached to them by the officer signing the certificate, when a degree of excellence has been attained within the limits shown in the fourth column

| ass. | Condition. | Col. III. | Col. IV. |
|---|---|---|---|
| \. | When the mean difference of the daily rate under the same condition of temperature and position, and during the same period, does not exceed .......................... | 2.$^s$00 | 0.$^s$75 |
| 3. | do. do. .......................... | 2.00 | 0.75 |
| :. | do. do. .......................... | 2.00 | 0.75 |
| \. | When the difference between the mean daily rate, Pendant up, differs from the mean daily rate, Dial up, by less than.......... | 5.$^s$00 | 2.$^s$50 |
| 3. | do. do. .......... | 10.00 | 5.00 |
| :. | do. do. .......... | 10.00 | 5.00 |
| \. | When the difference between the mean daily rate, Pendant up, and the mean daily rate in any position except Dial up is less than .......................... | 10.$^s$00 | 5.$^s$00 |
| \. | When the variation for 1° F. does not exceed | 0.30 | 0.15 |
| 3. | do. do. | 0.30 | 0.20 |

n addition to the above described certificates there will be nished records of rate for any timepieces deposited at the servatory for such a purpose. These records are meant to icate the performance of timepieces, and may take any n the person desires who enters the timepieces, subject to approval of the officer in charge. When such timepieces box chronometers, and they have been rated for a minim period of two months, and have been rated in the igerator and in the oven, and there has been no daily vari-n greater than 2$^s$.0 or than 0$^s$.3 for 1° F., certificates of class D will be issued with them.

Vhen such a timepiece is a clock, and it has been rated for inimum period of three months at ordinary temperatures, has been tested for compensation in temperature, and en the daily variation of rate has not exceeded 1$^s$.0, except re has been an attendant variation of the barometer in its as great as 0$^{in}$.70, and when the variation for 2° F. has not eeded 0$^s$.30, a certificate of the class E will be issued h it.

II.—*Cost of Certificates.*

| Designation. | Observatory charge. | Remarks. |
|---|---|---|
| Certificates: | | |
| Class A. | $7.50 | Discount of one-third when five movements are rated at the same time. |
| Class B. | 5.00 | do. do. |
| Class C. | 3.co | do. do. |
| Class D. | 7.50 | do. do. |
| Class E. | 20.00 | An additional charge for clock mounting will be made depending on its cost. |
| Rate records. | Per diem, $0.10 | An additional entrance fee of $0.25 will be charged for each movement. |

The experiment is being made of converting the clock Bond 367 into a clock of the highest grade of precision. For this purpose it has been re-mounted in a heavy cast-iron case, and hung between two brick piers. Arrangements have been introduced in it for the control of the pressure and the chemical constitution of the enclosing medium in which the pendulum swings.

The establishment of a clock of precision in this Bureau is of the greatest importance, since we are sometimes required to give daily rates of timepieces for a period comprising a week of continuously cloudy weather.

The Hillhouse clock has been cleaned, repaired, and adjusted to sidereal rate.

The clock Howard 191 has given us a considerable amount of trouble in transmitting the time signals. The successful transmission of time signals requires that the transmitting clock shall be an accurate timepiece, and yet that at the same time it shall be able to do the additional work of actuating electrical devices.

In the case of the Howard clock, the electrical apparatus is without that capacity for accurate and delicate adjustment which every telegraph instrument designed for continued use over long lines should possess; and although the devices employed in this clock are as efficient as any which have yet

ıe under my notice by other makers, yet one of the first ds of the Bureau is an alternative mean-time distributing k fitted with electrical time signal distributing apparatus, structed from the standpoint of the telegraph engineer, er than from that of the clock maker.

ur present time signal clock has been thoroughly repaired cleaned, adjustable contact springs have been inserted, our time signals will be distributed during the coming more satisfactorily than during the past, but it is unsafe ave the State Time Service dependent on this one clock.

bservations for time were made on the number of nights opposite the months following:

| | | | |
|---|---|---|---|
| 1883, June | 19. | December | 13. |
| July | 23. | 1884, January | 11. |
| August | 24. | February | 9. |
| September | 22. | March | 14. |
| October | 19. | April | 13. |
| November | 13. | May | 11. |

he observatory public time signals were changed on Nov. 1883, from the local time of the City Hall meridian, New k, to that of the seventy-fifth meridian west from Greenı, to accord with the general action of the railroads and s of the Eastern States. This move in the direction of lic convenience had been urged from the organization of Bureau. The original establishment of a meridian of York City as a State time, was with the ultimate object naking as much of a change toward the seventy-fifth idian time, as the public sentiment at the time of the pas- of the first time-law by the Legislature would allow. he January session of this year the Legislature amended time law to make legal the seventy-fifth meridian or stern Time" now in use.

ıe work of the Horological Bureau continued under the ge of Mr. R. W. Willson up to October, 1883, after which it devolved upon the writer. In Mr. Willson's departure, Bureau lost an officer of marked ability in the work in ch the Bureau is engaged.

## THE THERMOMETRIC BUREAU.

A larger number of thermometers than in any preceding year has been received for examination.

There has been a total of 6,390 thermometers examined, as follows:

17 Standard thermometers.
8 High temperature thermometers.
1 Minimum meteorological thermometer.
2 Maximum meteorological thermometers.
1 Thermometer below 0° F.
28 Ordinary meteorological thermometers.
6326 Physicians' clinical thermometers.
4 Thermometers to be pointed.
3 Thermometers to have the index restored.

There were also received for examination 9 hydrometers and 2 barometers. Of the above, 29 thermometers were broken in transit to the Observatory and 5 were broken during examination. As compared with our preceding year's work in this department, we have for the years given below:

| Year | 1880–81. | 1881–82. | 1882–83. | 1883–84 |
|---|---|---|---|---|
| Physicians' thermometers examined, | 1667 | 3811 | 5140 | 6326 |
| Other thermometers examined, | 290 | 741 | 155 | 64 |
| Total number instruments, | 1957 | 4552 | 5295 | 6390 |

The verification work of this Bureau has been conducted as usual by Mr. O. T. Sherman, and the Secretary, Mr. Robert Brown, has issued the certificates and conducted the correspondence.

Respectfully submitted,

LEONARD WALDO,
*Astronomer in charge of the Bureaus.*

# REPORT OF MR. SHERMAN.

YALE COLLEGE, June 9, 1884.

NTLEMEN:

3esides the routine work in the Thermometric Bureau, I ve during the past year devoted time and labor to the fol-ving subjects:

. I completed the outfit and mounting of my pendulum. servation with this has, however, been intermitted since nuary.

. From Sept. 5th to Feb. 5th, I followed the comet Pons-ooks, securing a long series of observations upon its form, arization, and position. These observations have been y partially reduced.

. The Observatory received near the end of December the gnetometer and dip-circle, which we owe to the generosity W. D. Ely, Esq., of Providence. They are both of the Kew tern. The constants of these instruments have been worked , and a considerable number of observations taken. Those h the magnetometer are confined to the Observatory ounds, those with the dip-circle, thus far, to the vicinity of w Haven.

The following are the results of the magnetic observations the observatory:

| Date, 1884. | Declination. | Hon. force in C. G. S. | Dip. |
|---|---|---|---|
| January, | 8° 54.'6 W. | 0.17901 | |
| February, | | | 72° 51.'6 |
| March, | 50. 7 W. | 0.17827 | |
| April, | 54. 1 W. | | |
| May, | 44. 1 W. | 0.17829 | |
| Total, | 8° 50.'9 | 0.17852 | 72° 51.'6 |

The values for January and April are the means of observa-ns on two dates. The others are single observations.

On July 17, 1878, Prof. T. E. Thorpe found, at a place not removed, the values: 8° 40.'6 W.: 0.17802: and 73° 5.'8.

. At Dr. Elkin's request a series of the measures of the meter of Venus has been commenced.

. The observations taken during the Transit of Venus, c. 6, 1882, await a final revision before being ready for the ess.

Respectfully,

ORRAY T. SHERMAN,

*Assistant in the Observatory.*

To the Board of Managers of the Observatory.

## REPORT OF DR. ELKIN.

YALE COLLEGE, June 13, 1884.

*To the Board of Managers of the College Observatory:*

GENTLEMEN: I beg leave to present the following statement of work with the Heliometer:

The instrument has been in my charge since January 15, 1884. I found it in good order, and both its mounting and that of the dome have proved most satisfactory.

The principal lines of investigation to which attention has been directed, are as follows:

1. The triangulation of the Pleiades. The interest attaching to this work will lie both in the new and independent determination of the relative positions of the stars of this important zodiacal group and in the comparison with the similar determination made with the Königsberg Heliometer nearly half a century ago, as well as with the later Paris results. The plan adopted will furnish, it is hoped, trustworthy tests of the reliability of the instrument both for absolute and relative distances and angles of position. From February 24th, the date of the arrival of the reversing eye-pieces from Messrs. Repsold, to April 12th, after which the stars are lost in the sun's rays, about one-third of the proposed plan has been accomplished. As the group will come into favorable position for observation during the last four months of the year, there is, therefore, all reasonable hope to finish the work during that time.

2. A considerable amount of time has been devoted to the determination of places of the moon relative to stars within measuring reach of the Heliometer. The principal object in view is the determination of the parallactic inequality in the moon's motion, the deduction of which from meridian and other observations is, as is well-known, attended with some difficulty.

3. Advantage has been taken of the favorable opportunity afforded by the approaching inferior conjunction of Venus for a series of observations on the diameter of this planet, of which a number have been already secured.

4. The general investigation of the instrument has been in progress. Its equatorial adjustments, flexures, etc., have been repeatedly determined, the screw of the scale micrometer examined, and the latter has been altered with a view to the best determination of the errors of the scales.

The reductions of the observations have not been carried beyond the preliminary stage, on account of the unavoidable want of some of the elements of reduction. Most of the results have, however, been taken out roughly to ensure confidence in the instrument's remaining in good working order.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

With [illegible]

EPORT FOR THE YEAR 1884–5, PRESENTED BY THE

BOARD OF MANAGERS OF THE OBSERVATORY TO

THE PRESIDENT AND FELLOWS OF

From YALE COLLEGE.

# OBSERVATORY IN YALE COLLEGE.

## BOARD OF MANAGERS.

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## OFFICERS.

ROBERT BROWN, Jr., *Secretary.*
LEONARD WALDO, S.D., *Astronomer in charge of the Horological Bureau.*
ORRAY T. SHERMAN, B.A., *Astronomer in charge of the Thermometric Bureau.*
WILLIAM L. ELKIN, Ph.D., *Astronomer in charge of the Heliometer.*

# REPORT.

*the President and Fellows of Yale College :*

GENTLEMEN :—We submit herewith the reports of the Secrery and the Astronomers of the Observatory. These reports plain in detail the work done by the several officers during e past year.

Very respectfully,

THE BOARD OF MANAGERS,

*of the Observatory in Yale College.*

LE COLLEGE, June 22, 1885.

## REPORT OF MR. ROBERT BROWN, JR.

YALE COLLEGE, June 17, 1885.

*the Board of Managers :*

GENTLEMEN :—I have the honor to report that during the ar ending June 1st, 1885, the improvement of the Observary grounds has progressed as favorably as our restricted sources would permit.

Canner street, for a distance of six hundred feet East from ospect street, has been graded to a depth of 2–5 feet below natural grade, and the grounds abutting on each side have en sloped conformably to the cut, and in accordance with

your instructions, and the slopes seeded with grass. Elm trees have been planted on the north side, for the above named distance, or as far as is practicable until the bank on the steeper part of the street, east of the proposed extension of Hillhouse Avenue, shall have been reduced. The south side of this street for about 1000 feet east from Prospect street, and the east side of Prospect street, south from Canner street, had been similarly planted the previous year. The principal expense entailed by the grading of the above-named portion of Canner street, was comprised in the necessitated resetting of the skeleton fences to the new level, and the smoothing and seeding of the disturbed ground. The holes for the trees were excavated and the trees themselves furnished as part consideration for the earth allowed to be removed.

A concrete sidewalk has been laid on the south side of Canner street for a distance of about 415 feet eastward from the proposed line of Hillhouse Avenue extension, which was as far toward St. Ronan street as the imperfect filling of Canner street at that point would permit, and for the same distance the gutter has been cobble-stoned on the south side.

The City has taken the preliminary steps toward sewering Canner street from Whitney Avenue to the proposed extension of Hillhouse Avenue.

Two fires this Spring have considerably damaged the young growth of trees and shrubs near Highland street, and it seems very desirable that the fence be continued around the entire lot,—through Prospect, Highland and St. Ronan streets,—for which most of the requisite cedar posts are on hand.

A considerable number of small trees have been transplanted from the adjoining undergrowth into the Observatory lot proper,—Beeches, Oaks of three species, Tulip trees, Dogwood, Sugar and Swamp Maples, Ash, Sassafras, etc., nearly all of which are doing well. The severe ice-storm of the winter of 1883–4 seriously damaged many of our forest trees, and to save them it became necessary last year to procure the services of an expert tree-pruner for their preservation, and with very satisfactory results. The ravages of insect and fungous enemies upon a few of our finer trees have been checked, with a promise of complete recovery in a few years. Two trees—chestnuts—were killed by lightning, on the northern portion of our grounds, last summer.

For contributions to the Library of the Observatory, we are under obligations to the following institutions and persons:

The Directors of the following Observatories:—

Observatoire Royale de Bruxelles.
Observatory of Trinity College, Dublin.
Lord Crawford's Observatory, Dun Echt.
Royal Observatory, Greenwich.
Harvard College Observatory.
Observatorio Meteorológico Magnetico Central de Mèxico.
Observatoire Cantonal de Neuchâtel.
Radcliffe Observatory, Oxford.
Real Osservatorio di Palermo.
K. K. Sternwarte im Prag.
Kaiserl. Nicolai-Hauptsternwarte, Pulkowa.
Observatoire Impérial de Rio de Janeiro.
Observatorio Nacional de Santiago de Chile.
Observatorio Astronómico Nacional de Tacubaya.
Leander McCormick Observatory, University of Virginia.
Astronomical Observatory, Utrecht.
U. S. Naval Observatory, Washington.

Secretaria de Fomento de la República Mexicana.
Chief Signal Officer, U. S. Army.
Superintendent of the American Ephemeris.
Lords Commissioners of the Admiralty.
U. S. Coast and Geodetic Survey.
U. S. Naval Academy.
Königl. Preuss. Geodätische Institut.
Physikalisch-ökonomischen Gesellschaft zu Königsberg.
Library of the University of Cambridge.
Canadian Institute.
International Electrical Exhibition, Philadelphia.
J. D. and E. S. Dana.
E. C. Pickering.
H. A. Newton.
L. Waldo.
Wm. L. Elkin.
R. Brown, Jr.
Wm. W. Payne.
Jeweler's Circular and Horological Review, New York.
Jeweler's Journal, Chicago.
Julius Wanschaff.
James W. Queen & Co.
H. Sotheran & Co.
Ulrich Hoepli.

Very respectfully,

ROBERT BROWN, Jr.,

*Secretary of the Observatory.*

# FIFTH ANNUAL REPORT

OF THE

## ASTRONOMER IN CHARGE OF THE HOROLOGICAL BUREAU OF THE OBSERVATORY IN YALE COLLEGE, 1884–1885.

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*PRESENTED TO THE BOARD OF MANAGERS AT THEIR MEETING, JUNE, 1885, BY LEONARD WALDO.*

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*To the Board of Managers:*

GENTLEMEN—The present report refers to the work of the Horological Bureau during the year ending May 31, 1885.

The methods of comparing the time-pieces continue in general the same as during the preceding year. The system of watch trials is, with some unimportant variations in details, that recommended in my last annual report, and agrees with the scheme adopted at the Kew Observatory, England, and the Observatory at Geneva, Switzerland.

Owing to the necessary absence of the observer who conducts the time-piece ratings, there have been no trials brought to a conclusion in time for this report, and the usual tables of ratings are therefore omitted. For the reason referred to, the reception of time-pieces during the latter months of the year was discouraged, with the result that not so large a number of time-pieces as usual have been received. The number of time-pieces received as compared with the number in previous years is as follows:

| | |
|---|---|
| 1880–81 | 219 |
| 1881–82 | 53 |
| 1882–83 | 41 |
| 1883–84 | 87 |
| 1884–85 | 58 |

The experiments relating to the establishment of a clock of precision for our watch-rating standard have been continued

the case ot clock "Bond 367," and the results of our expe- ence in the matter are being embodied in the new clocks of ·ecision now approaching completion at the works of one of ır leading clock companies.

An entirely new and very satisfactory mercury cup relay for curing the transmission of our time signals has been devised. y means of this relay, the length of the time signal break n be adjusted to the greatest nicety, and failures of the sig- ıl from imperfect relay contacts are completely avoided. An aborate, self-regulating-in-temperature watch-rating appa- tus has been sent to the Bureau by one of its friends, and ill be presented to the Bureau after any changes suggested its use have been made in its construction.

Two other friends of the Bureau have signified their inten- on of presenting to the Bureau a new clock of precision, as on as the necessary plans for its construction have been reed upon, and the standard clock can be constructed.

In December, the Transit instrument was dismounted and e wooden casing surrounding the piers removed. The brick ers were then coated with Portland cement, with the result at the azimuth and level have been much more constant since e change.

A collimator, consisting of an uncorrected lens of 267.1 feet cal length, through which a brass screw head set in a brick er to the south of the Transit instrument may be viewed, s been erected.

The level, having been taken apart, without result, to see nether there was no way by which its bubble length could be ortened, has had its division value redetermined. This value as found to be

$$0.''98365=0.^{s}067104.$$

December, 1884, at about 65° F.

Time observations were made on the following number ot ghts for each month during the year:

| | | | |
|---|---|---|---|
| June, | 9 | December, | 9 |
| July, | 11 | January, | 12 |
| August, | 12 | February, | 16 |
| September, | 20 | March, | 14 |
| October, | 8 | April, | 6 |
| November, | 9 | May, | 6 |

A serious deficit in the finances of the Observatory is threatened by the sudden termination on the part of the State Legislature of the contract by which the Observatory has been paid for its Time Service to the State at large. The Joint Standing Committee on Appropriations reported to the House of Representatives on March 5, 1885, the bill by which this contract was practically terminated.

The report was made without a hearing at which any of the following interests at stake had been heard from; viz: The Railroad Commissioners who proposed the law and the contract originally; the clock and watch manufacturers; the mayors, or other public officers of the cities of the State; the Telephone and Telegraph Companies; the Observatory.

There were no reasons assigned in the debates which preceded the final success of the bill, other than those of economy to the State, as to why the service should not be continued, at least until the Observatory, which had gone to very considerable expense in preparation for this service, had been properly reimbursed for its outlay. It is hoped that the next legislature will reconsider the action on this subject and continue a State Time Service which so far has received only words of commendation.

Respectfully submitted,

LEONARD WALDO,

*Astronomer in charge of the Horological Bureau.*

# REPORT OF MR. SHERMAN.

YALE COLLEGE, June 1, 1885.

*o the Board of Managers of the Observatory in Yale College:*

GENTLEMEN: During the year from June 1, 1884, to June 1, 85, the Thermometric Bureau has been called upon to ex- nine and report upon the following instruments:

| | |
|---|---|
| Clinical Thermometers, . . . . . . | 5580 |
| Meteorological Thermometers, . . . . | 57 |
| Physical Standards, . . . . . . | 22 |
| High Temperature Thermometers (100° to 300° C.), . | 20 |
| Low Temperature Thermometers (0° to − 40° C.), . | 6 |
| Pointing, . . . . . . . | 4 |
| Index restored, . . . . . . . | 5 |
| Thermometers sealed for seasoning, . . | 224 |
| Hydrometers, . . . . . . . | 2 |
| Total (omitting the thermometers sealed), . | 5696 |

During this interval nine thermometers have been broken handling, and twenty-one have been received broken. The crease in the sum total, as compared with that for the pre- ding year is due to the general depression in business. The rcular generally issued,* the property list, and a financial atement are appended.

In October last, when placed in charge of the Bureau, it as made a part of my duty to conduct especial investigations a scientific character. Outlines of four such investigations ere deposited with your Secretary. Two of these have been ought to a stage where it is possible to show some result.

### STUDY ON THERMOMETERS INTENDED TO MEASURE TEMPERATURES FROM 100°—300° C.†

It is well known that when a thermometer is heated above a rtain point, the mercury column is permanently displaced th regard to the scale.‡ The position of the point depends on the constitution of the glass forming the bulb, and upon e previous use of the thermometer. For certain glasses

* The circular will be sent to any address on application.

† See also Amer, Jour. Sci., July, 1885.

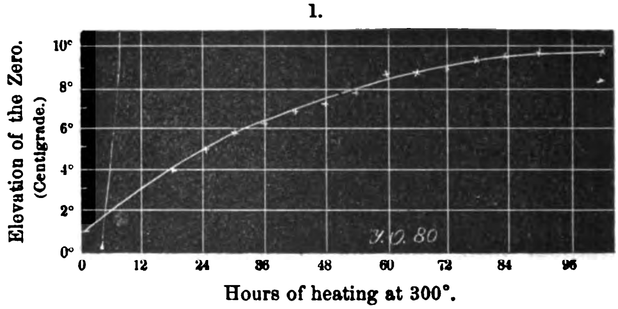
‡ Transactions of the Royal Soc., Edin. Vol. xxix, Pt. II.

designated by the thermometer maker as German or American soda, and Cornish, the elevation upon a new thermometer begins at 111°. For a flint or crystal tube the point is nearer 200°. Mills records 256° as his highest observed limit, 48° as his lowest. Our experience presents nothing lower than 110° nor higher than 255°. The latter point is obtained with English flint or French crystal.

By much use or long heating the displacement frequently amounts to ten degrees Centigrade, and may amount to twenty-six degrees.* To assign corrections to points so easily displaced is evidently nugatory. The Observatory has therefore hitherto confined its corrections to points below that at which the ascent began.

If now the thermometer be exposed to a high temperature for some hours the successive positions of the ice point will be found to arrange themselves in a curve similar to that in

1.




the adjoining figure. Thus for the first eighteen hours during which the thermometer Y. O. 80 was held at 300° Centigrade, the zero point was elevated 3°; for the second eighteen hours the elevation was 2°.2, for the succeeding periods 1°.7, 1°.1, 0°.8, 0°.3, respectively. The elevation evidently becomes less and less, and the curve becomes more nearly parallel to the axis of abscissas.† This same thermometer placed in a bath of 200°, immediately after the last observation rose two-tenths of a degree in the first twelve hours, but no change was detected in the following hundred and eight.

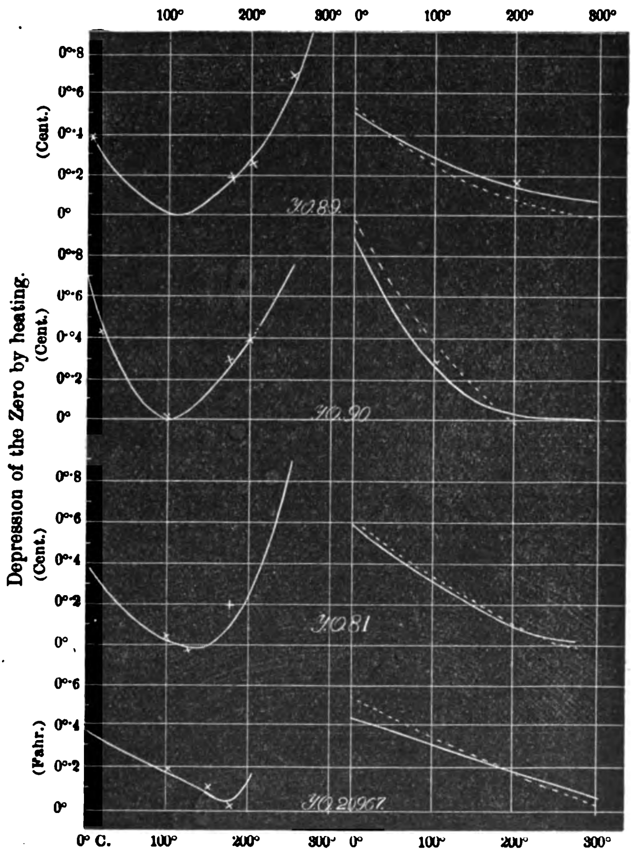
The question presents itself, What is the behavior of the thermometer after such treatment? First as regards the action

* Crafts, Comptes Rendus, 1882, 1883.

† Weber, Metronomische Beitrage. No. 3.

of the zero. In the adjoining cut we have compared the motion of the zeros of four thermometers before and after treatment. In the first series the influence of the rise is evident. The second is free therefrom. The movement of the zero for higher temperatures is similar to that for lower. That is, the mere fact of heating the thermometer now produces no distortions from which the instrument will not sensibly recover.

2.




Before heating. After heating.

Movement of the Zero.

Does the instrument after treatment repeat its readings when exposed to similar conditions? Do its indications vary in time? We have observed the corrections to the following

treated thermometers on Feb. 16, March 9, and 22, and April 15. The record is given in the adjoining table.

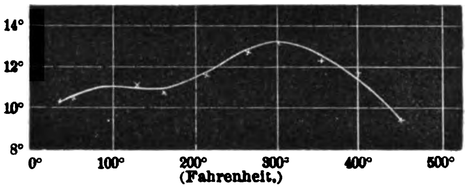
| | Feb. 16. | March 9. | March 22. | April 15. | Feb. 16–April 15. |
|---|---|---|---|---|---|
| | | Y. O. 81 (Cent.) | | | |
| 0° | −6°.6 | −6°.6 | −6°.6 | −6°.5 | |
| 100° | −5.85 | −5.78 | −5.76 | −5.68 | −0.16 |
| 200° | −6.3 | .... | .... | −6.1 | |
| | | Y. O. 89 (Cent.) | | | |
| 0° | −5°.5 | −5°.5 | −5°.5 | −5°.5 | |
| 100° | −4.3 | −4.0 | −4.1 | −4.0 | −.01 |
| 200° | −5.3 | .... | .... | −5.1 | |
| | | Y. O. 90 (Cent.) | | | |
| 0° | −8°.9 | −8°.9 | −8°.6 | −8°.5 | |
| 100° | −6.8 | −7.0 | −7.0 | −6.9 | −0.06 |
| 200° | −6.3 | .... | .... | −6.4 | |
| | | Y. O. 20967 (Fahr.) | | | |
| 0° | −16°.8 | −16°.9 | −16°.9 | −17°.0 | |
| 212° | −18.8 | −18.4 | −18.6 | −18.5 | |
| 387° | −25.2 | −25.2 | .... | .... | +0.17 |
| 420° | −27.8 | .... | .... | −28.2 | |

On all of these instruments the closeness of the graduation renders an error of observations of a tenth not improbable, so that with one exception, there is no difference which seems worthy of remark. These observations indicate that after treatment the thermometer is as serviceable as a measure of temperature ranging from 0° to 300° C. as the standard to which we are accustomed is for the range 0° to 100°. In the curve representing the movement of the zero, the record of April 15 is represented by a dotted line, that of February 16 by the full line. The former are slightly more curved than the latter. Again, in the final column of the preceding table are given the mean differences between the corrections due on Feb. 16 and April 15. Both of these differences we would interpret as small effects still occurring in the bulb, such as happen in every new thermometer, rather than as evidence that the instrument does not repeat itself.

It is of interest to ask what is the nature of the change which has been effected in the glass. If we compare the errors before and after treatment we obtain the following differences.

| | Y. O. 81. | Y. O. 89. | Y. O. 90. |
|---|---|---|---|
| 0° | 4°.0 | 4°.9 | 7°.5 |
| 100° | 2°.8 | 2°.9 | 6°.6 |
| 200° | 4°.6 | 4°.0 | 4°.4 |

The differences for Y. O. 20967, upon which the points ot
mparison are more frequent, are given in the adjoining
rve.




These differences indicate a change in the co-efficient
expansion of the glass. The amount for the interval 0°–
o is readily calculated and presents us with the following
lues:

| | | | |
|---|---|---|---|
| Y. O. | 81, | $100\,\delta\beta =$ | $-0.000046$ |
| Y. O. | 89, | $=$ | $-0.000022$ |
| Y. O. | 90, | $=$ | $-0.000003$ |
| Y. O. | 20967, | $=$ | $+0.000026$ |

lues similar to the first two have been previously observed
Weber, and by Crafts. The latter two are, as far as my
owledge goes, without precedent.

Again, if the thermometer be preserved at ordinary temper-
ıres, similar changes occur. We may instance the elevation
the zero with time. Its law is similar to that of the eleva-
n produced by heating. Or, analogous changes occur in
variation of the fundamental length-interval and the coeffi-
nts of expansion.

All of these facts—the condensation of the material forming
bulb; the consequent increase of its intermolecular attrac-
n, the dependence of the point at which the zero begins to
e upon the chemical constitution of the glass, the similarity
the changes produced by time, the regularity of these
anges, seem to indicate that the cause for the one, as was
ng since suggested for the other, is a partial separation of
crystalline from the amorphous bulb-constituents. If this
w is correct, it argues well for the stability of the treated
trument. The change will have been produced at the ex-
nse of its natural life. But then, few thermometers are per-
tted to die of old age.* The correctness of this view is the
ject of a separate research.

The greater portion of the thermometers now offered in t

* Since writing the above I have been informed by a maker that the way
nake thermometers good is to keep them in salt and ice for a long while.

market are affected by this error. It is believed that an Observatory certificate that a thermometer has been freed therefrom will have value. It is therefore proposed to undertake at the Observatory, for a moderate charge, the necessary treatment of thermometers sent to us for that purpose.

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## BEHAVIOR OF THE THERMOMETER WHILE SUFFERING A CHANGE OF TEMPERATURE.

A second investigation undertaken in accordance with the outline submitted to you upon taking charge of the Bureau, consists of an analysis of the state of the thermometer while suffering a rapid change of temperature.

The thermometer is essentially an instrument for comparing constant thermal conditions. In many cases, however, the physicist finds it of importance to observe an instantaneous and changing temperature; as, for instance, in investigating the law of cooling or the discussion of observations with Violle's exposed bulb. In such cases the changing is treated as though it were a static reading. Such a reading is, however, disturbed both by distortion of the bulb and by the friction of the mercury upon the glass. It has seemed not out of place to attempt to interpret the instantaneous reading.

If a thermometer be plunged into a bath whose temperature is very different from its own, its initial is in the direction contrary to its final motion. If the bulb be of such dimensions that its parts receive the heat practically simultaneously, and if its scale be open, the effect becomes evident to the naked eye. In two thermometers which we have especially examined, F. G. Greiner 600 and F. G. Greiner and Geissler 536*b*, the depression for a difference of temperature of 47° C. amounts to 0°.90 C. and 0°.73 C. respectively. The record is given in the adjoining table:

| Diff. of Temp. | 600. Depression. | 600. Elevation. | 536*b*. Depression. | 536*b*. Elevation. |
|---|---|---|---|---|
| 47° C. | −0°.90 | .... | −0°.73 | +1°.04 |
| 40 | −0 .75 | .... | −0 .70 | +0 .88 |
| 30 | −0 .50 | +0°.47 | −0 .55 | +0 .64 |
| 20 | −0 .29 | +0 .32 | −0 .32 | +0 .37 |
| 10 | −0 .14 | +0 .30 | −0 .16 | +0 .27 |

If the circumstances are such that the bulb is exposed slowly, or if only a portion thereof receives heat at once, the effect will be disguised and the column may appear stationary.

The reason is evident: the glass being heated or cooled

fore the mercury, the volume of the bulb is greater or less an the volume corresponding to the temperature of the ercury. We have chosen an exagerated case, but as long as e thermometer is rising or falling a similar condition must ist.

Again, if a thermometer with very small bore be taken from constant temperature, allowed to rise slightly, and replaced the bath the reading will continue slightly too high. Perps, however, the effect of friction is most strikingly shown comparing the times at which the column passes each fifth gree upon sudden immersion.

| | | | | |
|---|---|---|---|---|
| For falling temperature, | 2°.36 | 4°.54 | 9°.39 | 33°.09 |
| For rising temperature, | 2 .31 | 4 .16 | 7 .57 | 15 .52 |

The question before us, then, is whether it is possible to rive from the disturbed reading the temperature of the ass, the temperature of the mercury and the effect of friction.

If we represent by $\tau_o$ the apparent temperature, by $\tau_g$ the mperature of the glass, by $\tau_m$ the temperature of the merry $\beta$, the coefficient of expansion of the glass, $\gamma$ the coefficient of expansion of the mercury, F and F′ the corrections pending upon friction, we have at once from the theory of e thermometer; for a rising temperature,

$$\tau_o = \tau_m - \frac{\beta}{\gamma}(\tau_g - \tau_m) - F,$$

a falling temperature,

$$\tau_o = \tau_m + \frac{\beta}{\gamma}(\tau_m - \tau_g) + F'.$$

When the temperature of the mercury remains constant and glass changes, the value of the depression or elevation is ven by

$$\tau_o - \tau_m = \pm \frac{\beta}{\gamma}(\tau_g - \tau_m).$$

If, now, we consider that the depression takes place only ile the heat is making its way through the glass, and that moment of turning marks the moment of accession of heat the mercury, we are in a position to measure the temperae of the glass when the flow of heat commences. Again, uming that the several ordinates of the curve which express variation of temperature in the glass are proportional to differences of temperature at the two sides of the glass, we y express its instantaneous temperature by

$$\tau = \tau_m + (u - \tau_m)\int \frac{\tau x\, \delta x}{D} = \tau_m(1 - c) + uc,$$

where $u$ represents the final reading of the thermometer and $\tau_m + c$ the mean temperature of the glass for a difference of temperature of 1°.

In the case before us $u = 26°.636$ R and 0° R, and assuming $\beta = 0.0000214$, $\gamma = 0.0001814$, we readily have

$$\begin{array}{llll} \tau_o = -0°.46\ \text{R} & \tau =_m 0° & \tau_g = \ 3°.23 & c = 0°.147 \\ \tau_o = \ 26°.93\ \text{R} & \tau_m = 26.50 & \tau_g = 23°.20 & c = 0°.138 \end{array}$$

Replacing the value $\tau_g$ by its expression in terms of $\tau_m$, as given above, we readily obtain; for a rising temperature,

$$\tau_m = \frac{\tau_o}{1 + \frac{\beta}{\gamma}c} + \frac{cu\,.\,\frac{\beta}{\gamma}}{1 + \frac{\beta}{\gamma}c} + \frac{F}{1 + \frac{\beta}{\gamma}c},$$

for a falling temperature,

$$\tau_m = \frac{\tau_o}{1 + \frac{\beta}{\gamma}c} + \frac{cu\,.\,\frac{\beta}{\gamma}}{1 + \frac{\beta}{\gamma}c} - \frac{F'}{1 + \frac{\beta}{\gamma}c},$$

which in the present case gives us readily

$$\tau_m = \frac{\tau_o}{1.0173} + 0.46 + \frac{F}{1.0173},$$

$$\tau_m = \frac{\tau_o}{1.0162} \qquad - \frac{F'}{1.0162}.$$

From a series of such equations derived under similar conditions from thermometers suited to give a series of values of F and F′, or from a series where F and F′ are varied by the varying position of the thermometers, we would be able to directly observe the law of cooling, or, assuming Dulong and Petit's well known expression, we would be able to separate the effect of friction from the observed values. An example derived from the latter assumption follows, though accuracy lies not therein:

| Thermometer Rising. | | | | | Thermometer Falling. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Time. | $\tau_o$ | $\tau_m$ | $\tau_g$ | F | Time. | $\tau_o$ | $\tau$ | $\tau^g$ | F |
| $0^s.$ | 0° | +0.46 | 4°.30 | 0°.00 | $0^s.$ | 25° | 24.60 | 20°.54 | 0°.00 |
| $1^s.006$ | 5° | 5.37 | 8°.49 | 0°.00 | $0^s.87$ | 20° | 19.64 | 16°.40 | +0°.04 |
| $2^s.311$ | 10° | 10.32 | 12°.71 | 0°.03 | $2^s.23$ | 15° | 14.09 | 12°.02 | +0°.67 |
| $4^s.162$ | 15° | 15.43 | 17°.07 | 0°.23 | $4^s.54$ | 10° | 8.32 | 7°.10 | +1°.52 |
| $7^s.573$ | 20° | 20.82 | 21°.67 | 0°.71 | $9^s.39$ | 5° | 3.55 | 3°.02 | +1°.37 |

. note has been published in the American Journal of ence for May, 1885, calling attention to Dr. Weber's result cerning the connection between the chemical constitution l residual elasticity of glass. The subject is of especial erest.

MAGNETIC MEASUREMENTS.

n addition to work in the Thermometric Bureau, investiga-ns have been continued with the magnetic instruments en by Mr. Ely. After October the increase of duties in the reau interfered with the regularity of the observations.

'he following measurements were made at the station near Observatory Building.

AGNETIC OBSERVATIONS UPON THE OBSERVATORY GROUNDS.

| Date. | Declination. | Horizontal Force. | Dip. |
|---|---|---|---|
| June 16 and 17, 1884, | 8° 56′ 19″ | 1.7836 | 72° 47′.06 |
| July 11 and 14, | 8 58 6.6 | 1.7862 | 72 47.63 |
| Aug. 11, 12, 14, | 8 59 19.4 | 1.7907 | 72 45.99 |
| Sept. 15, 16, 17, | 9 0 10.28 | 1.7781 | 72 50.05 |
| Oct. 13, | 9 5 46.14 | | |
| Nov. 12, | 9 6 9.2 | 1.7812 | |
| Jan. 14, 1885, | 8 59 41.5 | 1.7735 | |
| March 28 and 30, | 9 1 41.24 | 1.7753 | |
| April 22, | 9 2 42.8 | 1.788 | 72 47.64 |
| May 18, | 8 56 54.4 | 1.782 | |

Jumerous observations have been obtained in adjacent itions showing that these values are greatly affected by neighboring rocks. Their number is not sufficient to e the amount of disturbance.

'he following observations made in the localities named are orted:

| Locality. | Date. | Declination. | Horizontal Force. | Dip. | Total Force. |
|---|---|---|---|---|---|
| vidence, R. I., | June 20, 1884, | 11° 7′ 42″ | 1.7376 | 73° 16′.61 | 6.0638 |
| ble Beach, Conn., | July 22, 1884, | 9 25.8 | | 72 50.38 | 6.0762 |
| th End, Conn., | July 22, 1884, | 8 46.16 | | | |
| thouse Pt., Conn., | June 30, 1884, | | | 72 46.12 | 6.0673 |
| terville, Conn., | Aug. 2, 1884, | 9 6.24 | 1.7821 | | |
| | June 2, 1885, | | | 72 49.91 | 6.0535 |

am glad to acknowledge my indebtedness to Mr. Brown a considerable part of the calculation necessary to deduce se results.

## A MEASURE OF THE DIAMETER OF VENUS.

The following observations were obtained by a Grubb filar micrometer, attached to the eight inch equatorial presented to us by Mr. Reed. The micrometer is essentially represented in figure 2, modified as in figures 5, 7, 8, of the article Micrometer in the ninth edition of the Encyclopedia Britannica. The equality of the several runs of the screws was tested under the microscope by Robert Brown, Jr., Secretary of the Observatory. The departures from the mean values are given in the following table: the unit being the ten thousandth of a revolution.

### DEPARTURES FROM EQUALITY OF THE DIVISIONS OF THE MICROMETER SCALE.

| | Right Hand Screw. | | | | | Left Hand Screw. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st Series. | 2d Series. | 3d Series. | 4th Series. | Mean. | 1st Series. | 2d Series. | 3d Series. | Mean. |
| 0– 1 | — 6 | —10 | 0 | —11 | — 6 | — 7 | — 6 | 0 | — 4 |
| 1– 2 | —31 | — 5 | + 1 | —16 | —13 | — 3 | + 6 | —10 | — 2 |
| 2– 3 | — 1 | 0 | + 1 | +14 | + 3 | — 3 | + 1 | 0 | 0 |
| 3– 4 | —16 | 5 | + 6 | + 4 | — 3 | +27 | +21 | 0 | +16 |
| 4– 5 | + 9 | —35 | +11 | +14 | 0 | —28 | + 1 | + 5 | — 7 |
| 5– 6 | — 6 | +10 | — 4 | — 1 | 0 | —28 | — 9 | —10 | —12 |
| 6– 7 | —11 | — 5 | — 4 | — 1 | — 5 | — 3 | — 4 | 0 | — 2 |
| 7– 8 | —16 | —10 | + 6 | + 4 | — 4 | +22 | — 9 | +15 | + 9 |
| 8– 9 | +24 | +15 | +21 | + 4 | +16 | + 2 | + 6 | +20 | + 9 |
| 9–10 | —26 | +10 | — 4 | + 4 | — 4 | —33 | +11 | +10 | — 4 |
| 10–11 | —11 | +15 | —19 | —11 | — 6 | + 3 | +21 | 0 | + 8 |
| 11–12 | — 1 | 0 | — 4 | —21 | — 6 | + 8 | — 9 | — 5 | — 2 |
| 12–13 | — 1 | —20 | —24 | —11 | —14 | — 2 | + 1 | + 5 | + 1 |
| 13–14 | —11 | —10 | + 6 | — 1 | — 4 | —18 | — 4 | —15 | — 9 |
| 14–15 | — 1 | +20 | —14 | —11 | — 1 | —18 | —14 | + 5 | — 8 |
| 15–16 | —21 | — 5 | + 1 | +24 | 0 | — 2 | — 9 | + 5 | — 2 |
| 16–17 | — 6 | +35 | — 4 | —21 | + 1 | —13 | + 6 | +10 | + 1 |
| 17–18 | —16 | — 5 | + 1 | — 1 | — 5 | + 3 | + 1 | — 5 | 0 |
| 18–19 | + 4 | +25 | —11 | —11 | + 2 | — 2 | — 4 | + 5 | 0 |
| 19–20 | +24 | —10 | —19 | — 6 | — 3 | +13 | — 9 | 0 | + 1 |
| 20–21 | +14 | +40 | + 1 | + 9 | +16 | — 7 | —14 | +30 | + 3 |
| 21–22 | +19 | — 5 | —14 | +14 | + 6 | +18 | —14 | — 5 | 0 |
| 22–23 | + 4 | +15 | +16 | + 9 | +11 | +13 | + 1 | —40 | — 6 |
| 23–24 | +14 | — 5 | +11 | —11 | + 2 | + 3 | + 6 | 0 | + 3 |
| 24–25 | + 9 | +20 | + 6 | — 1 | + 8 | +33 | +16 | —15 | +11 |
| 25–26 | +14 | — 5 | +16 | —11 | + 5 | —— | —— | 0 | 0 |
| 26–27 | +14 | —30 | + 1 | —14 | — 7 | —— | —— | +10 | +10 |
| 27–28 | + 4 | + 5 | +11 | +34 | +13 | —— | —— | —— | —— |
| 28–29 | +29 | —15 | 0 | —21 | — 2 | —— | —— | —— | —— |
| 29–30 | — 6 | —15 | + 1 | —19 | 0 | —— | —— | —— | —— |
| 30–31 | —11 | —10 | | — 6 | — 9 | —— | —— | —— | —— |

The observations in the following series falling almost

tirely between the fourteenth and nineteenth divisions, ese variations have been deemed negligable.

By comparison of the mean linear values of a revolution as rived from each series it is found that

1 revolution of the left hand screw = 1.0064 of the mean of both.
1 " " right hand screw = 0.9936 " " " "

The screws being designated right or left according as they e upon the right or left hand of the observer facing the crometer so placed that its scale is erect. Throughout these asures the mean of the interval measured upon both screws s been employed.

The value of a revolution has been obtained from star nsits. The temperature, the mean value of an interval, and e number of transits of a single interval upon which the ue depends are given in the successive columns of the adning table.

| Temperature in degrees (Cent.) | Mean value of a Revolution. | No. of single Transits. |
|---|---|---|
| $-10^\circ.10$ | $34''.3631$ | 367 |
| $-10.00$ | 34.3797 | 578 |
| $-8.17$ | 34.3489 | 300 |
| $+5.07$ | 34.3178 | 835 |
| $+18.79$ | 34.2724 | 839 |
| $+21.25$ | 34.2819 | 441 |
| $+2^\circ.81$ | $34''.3273$ | |

m which we readily derive the value for the mean of the tance passed over by a single revolution of both screws, as

$$r = 34''.3289 + 0''.00355\,(2^\circ.81 - \tau)$$

60°.95 F., the temperature to which the values in the prest work are referred, the value becomes 34″.2818.

In observing, the practice was to bring the two webs tangent either edge of the planet's disc and having read the scales interchange the webs and again read the scales. The mean the two intervals thus observed was accepted as the measе. To vary the conditions and the amount of personality, ries were conducted with the full number of eye pieces obnable; viz., powers 135, 160, 210, 320, 360.

The values belonging to each series, corrected for temperare and refraction have then formed part of a series of equans of the form

$$D - r(n+i) = O$$

in which D is the planet's diameter, $r$ the planet's geocentric distance, $n$ the corrected scale reading, $i$ the sum of the personal error of the observer, and the semi-thickness of the wires.

On Sept. 17th, the webs were observed to "fiddle." In remedying the evil the web was broken. A similar occurrence in October breaks the series into three. The first, extending from March 4 to September 17, 1884, are the only set strictly suited for discussion.

Of the five series, two, those with powers 135 and 360 present anomalous results. The cause for the discrepancy not being as yet ascertained, the values are not given. The remaining three afford

| | | | | |
|---|---|---|---|---|
| Power 160 | $D = 17''.371$ | $\pm 0''.049$ | $i = -2''.298$ | $\pm 0''.058$ |
| Power 210 | $D = 17.200$ | $\pm 0.045$ | $i = -1.925$ | $\pm 0.056$ |
| Power 320 | $D = 17.317$ | $\pm 0.041$ | $i = -1.174$ | $\pm 0.049$ |

At Dr. Elkin's suggestion a number of observations were taken with different apertures. The result is as follows: The diameter with 8 in. aperture is greater than the diameter with 6 in. aperture by $0''.22$. The diameter with the 8 in. aperture is greater than the diameter with 4 in. aperture by $0''.27$.

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A great amount of time has been spent with the spectroscope, but, on account of many untoward circumstances, no result can be reported. It is intended to frequently observe the spectrum of a number of stars and to catalogue that of those nebulæ which are within reach.

In March, the Chief Signal Officer placed a rain guage at the Observatory for the sake of comparing its collection with that at the signal service station. The results for the intervening two months are as follows:

| | Observatory. | Signal Service. |
|---|---|---|
| April, | 2.727 | 2.31 |
| May, | 2.928 | 2.61 |

Very respectfully,

ORRAY T. SHERMAN,

*Astronomer in charge of the Thermometric Bureau.*

## REPORT OF DR. ELKIN.

YALE COLLEGE, June 5, 1885.

*the Board of Managers of the Yale College Observatory:*

ENTLEMEN—I beg leave to lay before you my statement of k with the Heliometer during the past year.

he principal object of research has been the triangulation he Pleiades, to which work the instrument was devoted n September, 1884, to March, 1885. It was originally in-ded to confine the investigation to the stars measured at igsberg and to carry out only one method of triangu-on. The scheme has been extended, however, to include all stars in the Bonn Durchmusterung, within certain limits, n to the magnitude 9.2, making 69 stars in all, and also to ain a determination of the relative positions of the stars ch should be strictly comparable with the Königsberg k, viz: measurement of distances and angles of position of stars from Alcyone. The original plan contemplated only nited use of measures of angles of position, and the places he stars were to depend on measures of distance only from stars which form a large quadrilateral inclosing the major tion of the group, the relative position of these four stars irally to be ascertained with the greatest possible accuracy. h these plans have been carried out in a fairly complete ner, at least for the stars of Bessel's list; it may be advis- to secure next season the measures still wanting for those s not in Bessel's list, which, being all faint, were not possi- to get during the past, for the most part, hazy winter. observations have been all reduced provisionally; the l reduction cannot be undertaken until the results of the idian observations of the end stars of two zones serving to rmine the scale value and zero of position have been re-ed from the observatories which have kindly consented to e them.

f other observations I have to report:

easures of the Moon from neighboring stars have been e on 36 nights near the first and last quarters, which ild give 88 independent positions of the Moon. It appears sable, before devoting much more time to this work, to

test the value of the method by a complete reduction and di cussion of the measures already secured, which should prov sufficient for this purpose. It is therefore not proposed t carry on these observations at present. In connection wit this work the places of the three craters which have bee chosen as reference points have been determined each o several nights by measures from the Moon's limb, and th diameter of the Moon has been measured at opposition o seven occasions, generally in 36 directions. There has als been made a series on the diameter of Venus, 102 measures c 50 days with different powers and apertures, one on th outer ring of Saturn on 57 nights and a short series (22 obs of Titan referred to its primary.

The investigation of the division errors of the scales ha been carried as far as the determination of the errors of eac five-division line on both scales. The errors are small an regularly progressive, so that a more complete research ap pears hardly necessary except in special cases. In the centra portion of the scales each division has been investigated.

There have been various additions made to the workin appliances of the instrument. The motion in position ang has been facilitated by an extra handle and the oil lamp ill minating the scales has been replaced by a ½-candle inca descent lamp. This is of considerable importance, as certain positions of the instrument the oil lamp hung vert cally below the object glass, a state of things fatal to definitio and accurate work. The most important addition is, howeve the registering micrometer which Messrs. Repsold have ma for reading the scales. The principle consists in impressi on a Morse fillet the figures and divisions of the micromet head along with those of a fixed index. The instrument is exquisite design and workmanship, and has proved a co plete success in the line to which it was intended to be d voted. Besides the advantages of a permanent and indisputab record of the observation and absolute freedom from prej dice, the saving in time brought about by its use is ve considerable.

It is now proposed to devote the instrument to systemat investigations in stellar parallax, and a plan of work has be laid out and commenced which, if carried to completion, w furnish, it is hoped, a reliable value of the relative parallax

stars of the first and eighth magnitudes. As, however, the
rk is only just started, I beg leave to defer the details of the
eme until my next report.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1885–6, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY TO THE PRESIDENT AND FELLOWS OF YALE COLLEGE.

# OBSERVATORY IN YALE COLLEGE.

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# REPORT.

*the President and Fellows of Yale College:*

GENTLEMEN: — We submit herewith the reports of the
cretary and the Astronomers of the Observatory. These
ports explain in detail the work done by the several officers
ring the past year.

Very respectfully,

THE BOARD OF MANAGERS,

*of the Observatory in Yale College.*

ALE COLLEGE, June 22, 1886.

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## SECRETARY'S REPORT.

YALE COLLEGE, June 22, 1886.

*the Board of Managers:*

GENTLEMEN: — I have the honor to report that during the
r ending June 1st, 1886, the property under your control
been improved in the following respects: —

. Canner street, immediately west of St. Ronan street, has
n filled to grade on the south side; the deep fill of the
tion occupied by the sidewalk, for about 100 feet in length,
ing been omitted in the first grading. The curbstone and
cobble-stone gutter and the row of elm trees, with the
ss border to the sidewalk, have been continued to St.
nan street. In making this fill, a considerable part of the
ewalk on the north side has been excavated.

2. The concrete sidewalk previously laid on the south side of Canner street has been continued to Prospect street, and thence, on the east side of Prospect street, southwardly, to the southern boundary of your property; from which point the only gap in a continuous walk to the colleges, has been filled, in an obliging spirit, by our neighbors, with a wide flagstone sidewalk. The principal portion of the concrete walk on your land has been laid at the expense of anonymous contributions.

3. The sidewalk has been graded on the east side of Prospect street northwardly from Canner street, for about half the distance to Highland street, toward which its construction is being continued. This grading seems to be a prerequisite to a fence which will not require continuous repair, and which will restrain a considerable portion of the trespasses now committed with comparative impunity. Incidentally to the grading here spoken of, the drives in the Observatory grounds have been improved, and tendencies to washing away removed or reduced, a fair proportion of the expense being charged to repair account.

The merely routine duties of my office, while filling my time, present no items of interest not covered by other reports.

The contributions to the Library of the Observatory during the year ending June 1st, 1886, have been as follows:—

| | |
|---|---|
| Prof. H. A. Newton. | American Meteorological Journal, vols. 1 and 2, in numbers. 1884–5. 8°. |
| The Observatory. | Cambridge, Harvard College Observatory, 40th annual report of the Director. 8°. *Cambridge*, 1886. |
| The Lords Commissioners of the Admiralty. | Cape Town, Catalogue of 12,441 Stars for the Epoch 1880, from observations made at the Cape of Good Hope during the years 1871 to 1879. Edward James Stone. 4°. *London*, 1881. |
| —— | —— Catalogue of 4,810 Stars for 1850, from observations made at the Royal Observatory, Cape of Good Hope, during the years 1849 to 1852 under Sir Thomas Maclear. Reduced by David Gill. 8°. *London*. |

| | |
|---|---|
| Cincinnati, Publications of the Observatory. 8°.<br>No. 7. Observations of the Comets of 1880, 1881 and 1882, made under the direction of Osmond Stone, Astron., and Herbert C. Wilson, Astron. *pro tem.*<br>No. 8. Observations of the Comets of 1883, by H. C. Wilson, A.M., Astron. *pro tem.* *Cincinnati*, 1885. | Mr. Robert Brown. |
| Connecticut, Board of Railroad Commissioners, 33d annual report (1886) 8°. *Hartford*, 1885. | The Commissioners. |
| Córdoba, Resultados del Observatorio Nacional Argentino. B. A. Gould, Director. Vols. iii. and iv. Observaciones del año 1873. 4°. *Buenos Aires*, 1884. | Prof. J. D. Dana. |
| —— Resultados. B. A. Gould, Director. Vols. vii. and viii. Catálogo de las zonas Estelares $0^h$ á $xxiv^h$. 4°. *Cordoba*, 1884. | The Observatory. |
| Davidson, G. Methods and Results. U. S. Coast and Geodetic Survey. Appendices to the report for 1884. 4°. *Washington*, 1885.<br>No. 8. Run of the Micrometer.<br>No. 10. Heights of the Stations of the Davidson quadrilaterals from trigonometrical determinations. | The Author. |
| Dublin, Royal Society, Scientific Transactions. Vol. iii. (Series II.) in part. 4°.<br>VII. Notes on the Aspect of the Planet Mars in 1884, accompanied by sketches made at the Observatory, Birr Castle. By Otto Bœddicker, Ph.D.<br>IX. On the Changes of the Radiation of Heat from the Moon during the Total Eclipse of 1884, October 4, as measured at the Observatory, Birr Castle. By Otto Bœddicker, Ph.D. *Dublin*, 1885. | The Society. |
| Dun Echt, Observatory Publications. Vol. iii. Mauritius Expedition, 1874. Division II: Determinations of Latitude and Longitude. 4°. *Aberdeen*, 1885. | The Earl of Crawford and Balcarres. |
| —— Observatory Circulars, Nos. 94–122. | —— |

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| No. 4. O. Backlund. Zur Entwickelung der Störungsfunction. | |
| No. 6. Ed. Lindemann. Helligkeitsmessungen Bessel'schen Plejadensterne. | |

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No. 15. Dr. B. Hasselberg. Zur Spectroskopie des Stickstoffs. I, Untersuchungen über das Bandenspectrum.

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The Observatory. University of Virginia, Leander McCormick Observatory. Circulars Nos. 1 and 2.

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The Coast and Geodetic Survey. U. S. Coast and Geodetic Survey. Methods and Results. Longitudes determined by Electric Telegraph between 1846 and 1885. Appendix No. 11. Report for 1884. 4°. *Washington*, 1885.

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Very respectfully,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. WALDO.

[SIXTH ANNUAL REPORT OF THE HOROLOGICAL BUREAU.]

YALE COLLEGE, June 20, 1886.

*To the Board of Managers:*

GENTLEMEN:—The present report refers to the work of the Horological Bureau for the year ending May 31, 1886.

The methods adopted for the rating of timepieces will be found described in preceding reports. The number of timepieces received from the makers for rating, as compared with preceding years is as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1880–81 | 219 | 1882–83 | 41 | 1884–85 | 58 |
| 1881–82 | 53 | 1883–84 | 87 | 1885–86 | 74 |

The experiments in the construction of precision clocks have been continued. There being no very convenient facilities for this work at the observatory building, I have, with your permission, erected a private laboratory at my own expense, with a well built clock room, in the rear of the residence at 459 Prospect street. This laboratory is in working order and a series of experiments has been completed upon two precision clocks mounted therein, with every consideration for stability of support, and the control of their temperature and atmospheric conditions. The apparatus for temperature regulation is found to be efficient, and the work now in progress is expected to throw some new light on the law of compensation for clocks with detached escapements and mercurial-steel pendulums.

The time signals have been transmitted with greater uniformity than in any previous year, to the watchmakers and railroads.

Observations were made on the following number of nights each month during the year:

| | | | | | |
|---|---|---|---|---|---|
| June, | 8 | October, | 12 | February, | 4 |
| July, | 8 | November, | 5 | March, | 5 |
| August, | 5 | December, | 10 | April, | 9 |
| September, | 15 | January, | 4 | May, | 12 |

The threatened deficit in the finances of the Bureau, mentioned in my last report, was made up by a subscription from the following Railroads and Watch and Clock manufacturing companies toward the expense of maintaining the time signals and timepiece ratings for their benefit:

The New York, New Haven & Hartford R. R. Company.
The Housatonic R. R. Company.
The Naugatuck R. R. Company.
The Hartford & Connecticut Valley R. R. Company.
The American Waltham Watch Company.
The Elgin National Watch Company.
The Seth Thomas Clock Company.
The New Haven Clock Company.
The Springfield (Ill.) Watch Company.
The Hampden (Springfield, Mass.) Watch Company.
The Rockford Watch Company.

The prompt response which these corporations made to the request for their support, is a gratifying evidence of the value of the public services which the Bureau has maintained.

The State Legislature, at their last session, practically refused to reconsider their action in repealing their appropriation to the Observatory for the State Time Service, and the support of that service, if it is to be maintained, must now devolve upon the railroads. The views of the Bureau upon the justice of such support have already been given at length in a letter to the Railroad Commissioners of the State, which is published as an appendix to their report for the year 1886.

The personnel of the Bureau has included, during parts of the year, Mr. Frederic R. Honey, of the Scientific School, and Mr. Edward G. Fullerton, late of the Signal Service, U. S. A. These gentlemen have rendered efficient service in the work of the year.

Respectfully submitted,

LEONARD WALDO,

*Astronomer in charge of the Horological Bureau.*

## REPORT OF MR. SHERMAN.

YALE COLLEGE OBSERVATORY, June 20, 1886.

*'o the Board of Managers of the Observatory in Yale College :*

GENTLEMEN :—During the period from June 1, 1885, to June 1886, the Thermometric Bureau has been called upon to examine six thousand three hundred and fifty-five (6,355) instruments.*

These have included a range of comparison from $-40°$ . to $+300°$ C. Some have also been subjected to the treatment defined in last year's report, to render their indications able at high tempatures.

It is with great satisfaction that the Bureau notes a decided nprovement, since the first year of its operation, in the clinical thermometers of the better grades sent us by American akers.

Apart from the routine work studies have been conducted itending to display and eliminate the errors which adhere to thermometer reading on account of the individual peculiaries of the observation or instrument other than those produced y the composition of the glass, also other studies relating to ie thermometric standards; but in this as in the magnetic ork, many unavoidable interruptions, and the pressure of ie routine work, have combined to render no result ready for nnouncement.

The comparisons of rainfall at the Observatory and at the cal Signal Service Station, undertaken at the request of the hief Signal Officer, have been continued throughout the ear. The results are as follows :

*The numbers for the several years of operation of the Bureau are :—

| | | | |
|---|---|---|---|
| 1880—1881 | 1946 | 1883—1884 | 6392 |
| 1881—1882 | 4533 | 1884—1885 | 5717 |
| 1882—1883 | 5324 | 1885—1886 | 6355 |

MONTHLY RAINFALL IN INCHES.

| Month. | Observatory. | Signal Service. | Ratio. |
|---|---|---|---|
| June 1, 1885, | 1.59 inches. | 1.43 inches. | 1.11 inches. |
| July, | 2.89 | 2.51 | 1.15 |
| August, | 8.38 | 8.13 | 1.03 |
| September, | 0.96 | 0.77 | 1.25 |
| October, | 6.72 | 5.37 | 1.25 |
| November, | 4.74 | 3.49 | 1.36 |
| December, | 4.11 | 3.31 | 1.24 |
| January, 1886, | --- | 3.53 | --- |
| February, | --- | 5.95 | --- |
| March, | 4.37 | 3.19 | 1.37 |
| April, 1883, | 2.73 | 2.31 | 1.18 |
| April, 1886, | 5.20 | 3.21 | 1.62 |
| May, 1885, | 2.93 | 2.61 | 1.12 |
| May, 1886, | 3.66 | 2.73 | 1.34 |

Or; the Observatory has received twenty-four per cent. more rain than the Signal Service Station. The distance between the two is about a mile and a quarter. The Observatory gauge is on the ground, the Signal Service's gauge is on the very high roof of the Insurance Building.

The Equatorial has throughout the year been applied to spectroscopic work. Its outfit has, by your permission, been increased by the usual means of producing comparison spectra, by a Rowland flat grating, 14,347 lines to the inch, and by the means of attaching the same.

Announcements have been made as follows:—

(1.) The Spectrum of Nova Andromedæ, (Am. Jour. Sci., vol. xxx, Nov., 1885, p. 379.) Two bright lines were detected agreeing with two lines in the spectrum of the solar chromosphere, 1474 and 1250. This result agreed with that announced by Mr. Maunder of Greenwich, but was not obtained by any other spectroscopist.

(2.) Bright Lines in Stellar Spectra, (Am. Jour. Sci., vol. xxx, Dec., 1885, p. 475.) A large addition was made to the number of bright lines seen in the spectrum of $\gamma$ Cassiopeiæ and the existence of similar appearances in the spectra of other stars asserted. The announcement has met with criticism. In a note addressed to the Royal Astronomical Society of London, and submitted herewith, I have endeavored to

swer the questions raised before that Society and to show re fully the method of observation and the appearances served.

3.) Note on the Spectrum of Comet C. 1886, (Am. Jour. ., not yet published.) The comet presented to telescopic w a faint oval of light. By using no slit, carefully exclud- all foreign light and protecting the eye, there were de- ted more than the usual number of bands, so placed as to r considerable resemblance to a low temperature spectrum hydrocarbon.

A study was also made upon the spectrum of Nova Orionis, on account of difficulties in the way of the interpretation has not been published. Observations of the spectra of sun ts and protuberances have also been taken, as occasion ered.

t is expected to continue to employ the instrument in fol- ving the spectra of certain stars, and in gathering observa- ns of sun spots and protuberance spectra.

Very respectfully,

ORRAY T. SHERMAN,

*Astronomer in charge of the Thermometric Bureau.*

## REPORT OF DR. ELKIN.

YALE COLLEGE, June 14, 1886.

*To the Board of Managers of the Yale College Observatory:*

GENTLEMEN: — During the past year the work with the Heliometer has progressed as follows:

Some further observations of the Pleiades have been secured which complete the series obtained in the previous year; all the stars have now been observed on from ten to twelve nights, and a total of over 1600 measures of distance and 700 of position-angle are available for discussion. The essential and heavy parts of the reductions are completed, and there remain only one or two points of detail to be disposed of before the definitive results may be arranged for publication.

The principal observing work on my part, however, has been in connection with a scheme for determining the average parallax of the first magnitude stars as a first step towards the more comprehensive plan outlined by Dr. Gill and myself. What is proposed at present is to take the ten brightest stars in the Northern Hemisphere and observe them each from 16 to 20 times at epochs of maximum paralactic displacement, using a favorably situated pair of comparison stars, in some cases a double pair or four stars. It will be understood that it is not expected that each individual resulting parallax will be of very great accuracy from so limited a series, but that the mean of the ten parallaxes will give, it is hoped, a fairly reliable value for the average distance of the most brilliant stars. Arcturus, however, with its large proper motion, presents an object of especial interest, and it has been taken up in a more exhaustive manner with six pairs of comparison stars, five of which have been successfully followed up so far. The whole work is progressing satisfactorily, over 200 sets of measures having been made, and is rather more that half completed, the working plan extending until February, 1887.

Since September, 1885, Mr. Asaph Hall, Jr., has been engaged in observing with the Heliometer, the object in view being a determination of the mass of Saturn from measures of

itan. He has secured 49 complete sets (16 pointings) and 19 alf sets (8 pointings) of such measures. He has also observed arious stars for an independent determination of the instruental constants, and has investigated the division errors of art of the scale used in the observations of Titan.

No changes of consequence have been made with the instruent; incandescent lamps are now used for reading the circles f position and declination, the battery power being derived om three or four bichromate cells, which are easy to be cared r, and seem for our purpose to offer the simplest solution of e problem.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

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ERRATA.

| | | | | |
|---|---|---|---|---|
| Page | 5, | line | 4, | for *Osmond*, read *Ormond*. |
| " | 5, | " | 16, | " *zonas*, read *Zonas*. |
| " | 6, | " | 15, | " *Boréale*, read *boréale*. |
| " | 6, | " | 33, | after *Gradmessung*, insert period. |
| " | 7, | " | 11, | for *in*, read *im*. |
| " | 7, | " | 15, | omit *am 27 Mai, 1884*. |
| " | 7, | " | 17, | " *am 25 Mai, 1885*. |
| " | 7, | last line, | | insert *der*, before *Bessel'schen*. |
| " | 8, | line | 21, | for *Kaiserlichen*, read *Kaiserliche*. |
| " | 11, | " | 11, | " *tempatures*, read *temperatures*. |
| " | 12, | " | 3, | omit *inches*, after last column. |
| " | 12, | " | 13, | for *1883*, read *1885*. |
| " | 14, | " | 20, | " *paralactic*, read *parallactic*. |
| " | 14, | " | 32, | " *that*, read *than*. |
| " | 15, | " | 5, | before *part*, insert *the*. |

EPORT FOR THE YEAR 1886–7, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

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## OFFICERS.

ROBERT BROWN, M.A., *Secretary.*

WILLIAM L. ELKIN, Ph.D., *Astronomer in charge of the Heliometer.*

ASAPH HALL, JR., *Assistant Astronomer.*

# REPORT.

YALE UNIVERSITY, June 25, 1887.

*the President and Fellows:*

GENTLEMEN:—We herewith transmit to you the Report for e past year of the Secretary of the Observatory, and that of e Astronomer in charge of the Heliometer.

The three years period for which the subscriptions had been ade for the support of the work with the Heliometer exred with the last calendar year. A renewal of the subscripn has been generously granted for another period by the llowing ten persons, each paying one hundred dollars a ar:—

| | |
|---|---|
| AN ANONYMOUS FRIEND. | |
| ELIAS LOOMIS, | Class of 1830. |
| MRS. K. FELLOWES WHEELER. (Continuing her father's subscription.) | |
| CYPRIAN S. BRAINERD, | Class of 1850. |
| HUBERT A. NEWTON, | " " |
| ROBERT BROWN, | " 1857. |
| HENRY F. DIMOCK, | " 1863. |
| LEVI C. WADE, | " 1866. |
| GEORGE T. BLISS, | " 1873. |
| EDWARD W. SOUTHWORTH, | " 1875. |

The Trustees of the Bache Fund of the National Academy Sciences granted us a second appropriation of $600 to able Mr. Hall to make more complete his measurement of mass of Saturn. The work of the first year would probahave given a good determination of the planet's mass, but view of the importance of this constant in Physical tronomy it seemed desirable to continue the observations ough another year so as to obtain the best possible result. The expense of printing and distributing Dr. Elkin's moir upon the Pleiades, amounting to $650, has been rne by Professor Loomis.

The establishment of the Horological Bureau in 1879, was made with the express understanding, that the Bureau should be self-supporting and should under no circumstances become a pecuniary burden to the Observatory. The experience of eight years has clearly shown that as yet there is not enough demand for the testing of time-pieces in this country to justify the immediate continuance of this work. The largest number of watches presented in any one year to be tested has been 219, and during the past year this number has been reduced nearly if not quite to zero. The Astronomer who has had charge of the Bureau from its first organization has resigned his connection with the University. The watch and clock companies have in past years generously contributed towards the support of the Bureau, and the Observatory should hold itself in readiness to respond to any indications on their part that the resumption of its peculiar work, the testing of time-pieces, is desired and will be useful to them.

The Observatory time-service has been of very great advantage to the public, and should be continued so long as its expense can be provided for without burden to the University. Since the benefit accrues to the public throughout the whole State it is very proper that the State should itself bear the expense of it. This service will be carried on by Mr. Hall, the Assistant Astronomer.

The Thermometric Bureau was under the charge of Mr. Sherman until his resignation in November last. We regret the loss of Mr. Sherman's services, but the work of the Bureau is being well and faithfully done. Previous to his departure Mr. Sherman had been engaged in spectroscopic studies with the Reed Equatorial. Some interesting results of his work have been published by him in the scientific journals.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE OBSERVATORY, June 21, 1887.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report that during the year ending June 1st, 1887, the only notable improvement of the Observatory property permitted by our limited resources, has been the continuation of the grading of the sidewalk on the east side of Prospect street, from Highland street southwards, to meet the work of the preceding year. A part of this —from about 350 to 650 feet south of Highland street—being through hard rock, remains unfinished, although most of the rock has been removed. Except for this distance, of about 300 feet, the sidewalk has been graded and put in grass, and elm trees planted.

The contributions to the Library of the Observatory during the year ending June 1st, 1887, have been as follows:—

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| American Meteorological Journal, vol. 3, in numbers. 1886–7. 8°. *Ann Arbor*, 1886–7. | Prof. H. A. Newton. |
| American Ephemeris and Nautical Almanac for the year 1889. 1886. 8°. (2 copies). *Washington*, 1886. | Office of the American Ephemeris. |
| Armagh. Second Catalogue of 3300 stars, for the Epoch 1875, from Observations made at the Armagh Observatory during the years 1859 to 1883. J. L. E. Dreyer. 8°. *Dublin*, 1886. | The Observatory. |
| Bredichin, Th. Quelques remarques concernant mes recherches sur les comètes. 8°. *Moscow*, 1884. | The Author. |
| —— sur les anomalies apparentes dans la structure de la grand comète de 1744. 8°. *Moscow*, 1884. | —— |
| Cambridge. Harvard College Observatory, 41st Annual Report of the Director. 8°. *Cambridge*, 1887. | The Observatory. |

—— —— Annals of the Astronomical Observatory of Harvard College, vol. XVI. Observations of fundamental stars made with the meridian circle during the years 1870 to 1886. Prepared for publication under the direction of Joseph Winlock and Edward C. Pickering, by Wm. A. Rogers. 4°. *Cambridge*, 1886.

—— —— Henry Draper Memorial; First Annual Report of the Photographic study of stellar spectra conducted at the Harvard College Observatory. Edward C. Pickering, Director. 4°. *Cambridge*, 1887.

The Observatory. Cape of Good Hope. Annals of the Royal Observatory. Vol. II, Part I. Observations of the Great Comet 1882, II. 4°.

—— —— Results of meridian observations made at the Royal Observatory, during the years 1879, 1880 and 1881, under the direction of David Gill. 8°.

J. D. Dana. Córdoba. Resultados del Observatorio Nacional Argentino. Juan M. Thome, Director. Vol. v. Observaciones del año 1874. 4°. *Buenos Aires*, 1886.

J. D. and E. S. Dana. —— Resultados del Observatorio Nacional Argentino. B. A. Gould, Director. Catálogo General Argentino. Vol. xiv. 4°. *Córdoba*, 1886.

The Author. Davis, Wm. M. Thunder storms in New England in the summer of 1885. Report made for the New England Meteorological Society. 8°. *Cambridge*, 1886.

The Author. D'Engelhardt, B. Observations Astronomiques. Part I. 4°. *Dresden*, 1886.

The Author. Döllen, W. Stern-Ephemeriden auf das Jahr 1887, zur Bestimmung von Zeit und Azimut mittelst des tragbaren Durchgangsinstruments im Verticale des Polarsterns. 8°. *St. Petersburg*, 1886.

—— —— Zeitstern-Ephemeriden auf das Jahr 1886 für die Zeitbestimmung vermittelst des tragbaren Durchgangsinstruments im Verticale des Polarsterns. 8°. *St. Petersburg*, 1886.

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| inburgh. Astronomical Observations made at the Royal Observatory. Being vol. xv. for 1878 to 1886. Containing the remainder of the Star Catalogue, Discussion, and Ephemeris for 1830 to 1890. C. Piazzi Smyth. 4°. *Edinburgh*, 1886. | The Observatory. |
| neva. Rapport sur le Concours pour le réglage des Chronomètres pendant l'année 1885. Présenté à la Société des Arts, le 15 Mars 1886, par M. Em. Gautier. 8°. (2 copies). | The Observatory. |
| eenwich. Astronomical, Magnetical and Meteorological Observations made at the Royal Observatory in the year 1884, under the direction of W. H. M. Christie. 4°. *London*, 1886. | The Observatory. |
| vana. Observaciones Magnéticas y Meteorológicas del Real Colegio de Belen de la Compañia de Jesus. 4°. [3 Nos., Jan. to Sept., 1885.] *Havana*, 1885. | The College. |
| verford College Observatory, Longitude of, by Isaac Sharpless. [Amer. Phil. Soc., April 6, 1883.] 8°. | The Observatory. |
| velers' Circular and Horological Review. Numbers to June, 1887. 4°. *New York*, 1886–87. | The Publishers. |
| velers' Journal. Numbers to July, 1886. 4°. *Chicago*, 1886. | The Publishers. |
| locsa. Berichte von dem erzbischöflich Haynaldschen Observatorium über die daselbst in den ersten fünf Jahren ausgeführten Arbeiten. Carl Braun. 4°. *Münster i. W.*, 1886. | The Observatory. |
| rlsruhe. Veröffentlichungen der grossherzoglichen Sternwarte. Zweites Heft. W. Valentiner. 4°. *Karlsruhe*, 1886. | The Observatory. |
| erber, Felix. Über den Cometen 1865, I. 8°. *Breslau*, 1887. | The Author. |
| ipzig. Publicationen der K. Universitäts-Sternwarte. Heft. I. 4°. Carl Bruhns and H. Bruns. *Leipzig*, 1882. | The Observatory. |

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| The Observatory. | Mexico. Observatorio Meteorológico Central. Boletin del Ministerio de Fomento de la República Mexicana. Tomo x. Folio. [Semi-weekly numbers to May 26, 1886]. |
| The Observatory. | Moscow. Annales de l'Observatoire. Vol. x. 2 livraison. Th. Bredichin. 4°. *Moscow*, 1884. |
| The Lords Commissioners of the Admiralty. | Nautical Almanac and Astronomical Ephemeris for the year 1890. 8°. *London*, 1886. |
| The Author. | Newton, H. A. The Meteorites, The Meteors and The Shooting Stars. An Address before the Amer. Assoc. for the Adv. of Science, at Buffalo, Aug., 1886. 8°. *Salem*, 1886. |
| The Observatory. | Oxford, Radcliffe Observatory. Results of Astronomical and Meteorological Observations made in 1883, under the supervision of Edward James Stone. Vol. xii. 8°. *Oxford*, 1886. |
| The Author. | Pickering, Edward C. A Plan for the Extension of Astronomical Research. 8°. *Cambridge*, 1886. |
| —— | —— An Investigation in Stellar Photography, conducted at Harvard College Observatory. 4°. [Mem. Amer. Acad. Vol. xi.] *Cambridge*, 1886. |
| —— | —— Comparison of Maps of the Ultra Violet Spectrum. 8°. [Amer. Jour. Sci., vol. xxxii, Sept., 1886]. |
| The Observatory. | Prague. K. K. Sternwarte. Astronomische Beobachtungen im Jahre 1884. Enthaltend Originalzeichnungen des Mondes. L. Weinek, Director. 4°. *Prague*, 1886. |
| —— | —— —— Magnetische und Meteorologische Beobachtungen im Jahre 1885. L. Weinek, Director. 4°. *Prague*, 1886. |
| The Observatory. | Pulcowa. (Nicolai-Hauptsternwarte). Jahresbericht. 8°. *St. Petersburg*, 1886. |
| The Observatory. | Rochester. Warner Observatory. History and work, 1883–1886. Vol. I. 8°. (2 copies). *Rochester*, 1887. |

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| Santiago. Observaciones Meteorológicas hechas en el Observatorio Astronómico. José Ignacio Vergara, Director. 1882–84. *Santiago*, 1885. | The Observatory. |
| St. Petersburg, Académie Impériale des Sciences, Mémoires. VII^me^ Série, Tome xxxiv. 4°. *St. Petersburg*, 1886. | The Academy. |
| No. 2, Magnus Nyrén. Untersuchung der Repsoldschen Theilung des Pulkowaer Verticalkreises nebst Auseinandersetzung der angewandten Untersuchungsmethode. | |
| No. 3. Alexandre Shdanow. Recherches sur l'orbite intermédiaire de la Comète de Faye dans la proximité de Jupiter en 1841. | |
| No. 5. Hermann Struve. Über die Allgemeine Beugungsfigur in Fernröhren. | |
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## THE THERMOMETRIC BUREAU.

This department of the Observatory has cause to regret the departure, in November last, of Mr. Orray T. Sherman, under whose conscientious attention and supervision the Bureau has attained its present measure of usefulness. The number of instruments compared during the year ending June 1st, 1887, was 6,224, or about the same as during the previous year.

The improvement noted in last year's report,—both actual, and relative to foreign manufactures,—in the quality of instruments of American manufacture sent here for verification, appears to be fully maintained:—and the Observatory may rightly claim a large share of the credit of this improvement. Machinery for the more exact division of the scales seems to be the principal requisite—and that on the part of a few makers only,—to place them on a perfect equality with the best foreign manufacturers. It may now be fairly said—as it could not have been said before the institution of this Bureau—that the best clinical thermometers of American manufacture compare favorably with the best foreign manufactures, both in the smallness of the amount of the required corrections, and in their uniformity throughout the scale. Without greatly increased compensation to the manufacturer, it cannot be expected that more than a very small percentage of the clinicals of even the best makers, shall indicate the true temperature, at all points of the scale, within $0^{\circ}.1$, whereas thermometers with corrections, reliably ascertained, "large or systematically changing from one end of the scale to the other are not necessarily inferior for the most exact determinations." The very low prices to which competition has forced the lower grades are, of course, inconsistent with extreme accuracy, and account for the most of what is lacking when American manufactures, as a whole, are compared with the better grades of foreign, instruments which, almost alone, reach us. Too large a proportion of the clinical thermometers (foreign or American) sent to us for verification continue to come to us so soon after their manufacture that the corrections given are liable to change with a year's use. Physicians would obtain much more exact indications of temperature, if, estimating the probable annual breakage, they would provide

emselves with two or three years' supply of well made, well
aduated clinicals and obtain tables of corrections only after
e instruments were *known* to have attained a proper age of,
y, one or two years. The comparatively small demand for
inicals whose *age* as well as correction is certified, seems to
ply that the Medical Profession is not yet generally awake
the exactitude that is practicable in ascertaining body
mperature.

ROBERT BROWN,
*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 20, 1887.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—The work in connection with the Heliometer since my last report has progressed as follows:

The reductions of the measurement of the Pleiades made in 1884 and 1885 have been completed, the work passed through the press, and has been distributed as Part I of Vol. I of the Transactions of the Observatory. The general plan and scope of the work have been mentioned in my previous reports, but it may not be out of place to recall them briefly and summarize the results. The measurements furnish the places of 68 stars of the Pleiades relative to Alcyone, or all within a radius of about a degree of this central star down to the magnitude 9.2 of the Bonn charts. The final places result from the combination of the determinations by two independent methods, the comparison of which shows that for the stars brighter than ninth magnitude, at least, the systematic errors of both triangulations are comparatively small. A chief point of interest lies in the confrontation of the Yale work with the best results derivable from Bessel's triangulation of the group with the Königsberg Heliometer, made in 1830–1840, sufficiently long ago, probably, to show the character of the relative motions in the cluster. These prove to be, in general, very small,—so small that, except for about a dozen of the stars compared, another half century will probably have to elapse before any reliable conclusion as to the precise amount and direction of the displacements may be found. Of those stars, however, where this is the case, there are six which have a common drift falling not very far from that which they should show if they did not belong to the cluster, but if this latter were passing over them. In other words, the apparent displacements of these six stars are such that when the absolute motion of the group as a whole—which amounts to some 7″ since Bradley—is taken into consideration, their absolute motions are quite small. In this connection it is perhaps of

erest to note that this number, six, is about what we might
›ect to find as not belonging to the group, since on the area
l down to the magnitude under consideration there should
in general some seven or eight stars. In another way the
nparison with the Königsberg work is of interest, inasmuch
it furnishes evidence as to which one of two discrepant
ues for the screw-value of the Königsberg Heliometer is
ely to be nearer the truth, a point of considerable import-
e in view of the numerous results which depend upon this
ment. Finally, there is some little interest attaching to a
nparison of the Yale results with those obtained lately at
ris and Oxford as it discloses, I think I may venture to say,
weakness in part of the filar micrometer for such work
l shows the Heliometer triangulation to have not been
irely superfluous.

The observational work during the present year has been
ncipally the continuation of the measures for the deter-
nation of the mean parallax of the first magnitude stars.
e work is nearly completed, about 350 sets in all having
en obtained and the only deficient series are those on
cturus and Aldebaran, the wanting observations of which
l be secured it is hoped this summer and autumn. The
ter star has been followed up with three pairs of compari-
stars, on account of the large discrepancy between the
ults obtained at Pulkowa and that found by Prof. Hall at
shington—and I may state that given by one pair with the
liometer here. The reductions are under way.

The series of measures of Titan for the determination of the
ss of Saturn and the satellite's orbit has been continued by
. Hall, who has secured 27 complete and 14 half sets, mak-
in all with the measures of last year observations on more
n 100 nights. Mr. Hall has made considerable progress in
reductions.

We have also made further measures of the arc in Cygnus
l some on that in Eridanus and a series on the Sun's
meter at the request of Prof. Auwers.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1887–8, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

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## OFFICERS.

ROBERT BROWN, M.A., *Secretary.*
WILLIAM L. ELKIN, Ph.D., *Astronomer in charge of the Heliometer.*
ASAPH HALL, Jr., *Assistant Astronomer.*

# REPORT.

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YALE UNIVERSITY, June 25, 1888.

*To the President and Fellows of Yale University:*

GENTLEMEN:—We herewith present to you the Report of the Secretary of the Observatory, and that of the Astronomer in charge of the Heliometer.

The time service has been maintained throughout the year by Mr. Hall the Assistant Astronomer.

A telegraph line has been constructed through Division street to the Railroad, so that the Observatory clock is now directly connected with the telegraph system of the railroads.

Mr. E. M. Reed has manifested his continued interest in our work by purchasing from Messrs. Negus a new and first-class 56 hour Chronometer (No. 1734), and presenting it to the Observatory. This is a valuable and much needed addition to our instrumental equipment.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE OBSERVATORY, June 14, 1888.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report that during the year ending June 1, 1888, in closely following the spirit of your instructions, I have endeavored to make the labor of our single workman contribute as much as possible to the improvement of the appearance and market value of the property north of Canner street, in the hope that at an early day we may feel the benefit of the extension which has recently been taking place in the northern part of the city to the east of us. The improvements accomplished are:—

1. The completion of the line of shade trees—elms—on the east side of Prospect street, where pits about eight feet square and three feet deep were excavated in the rock and filled in with good loam. The seams in the rock are such that it is judged that when the trees shall have had the good start offered them, they will be able to send their roots far enough for their continued healthy support.

2. On the south side of Highland street, from the corner of Prospect street, eastward, twelve elms have been planted in the sidewalk, the line being interrupted, for the present, at points where excavation in rock would be necessary. The sickness of our laborer shortened the effective period for this work. For the rest of this line, the elms, which have now become scarce in our neighborhood, stand within our grounds, convenient to their destination, having been carefully pruned and root-pruned during the past two years, with this end in view.

3. On the north side of Canner street, from the proposed extension of Hillhouse avenue to St. Ronan street, elm trees have been planted in the sidewalk. Preliminary to this the bank, ranging from two to eight feet high, and about 300 feet long, in the western section was cut down to a grade of two feet above the curb line, at the highest part and tapering to the ordinary grade at each end. About 100 feet, in length, of this

k remains to be removed for about half the breadth of the walk, enough having been removed to make room for the ss edging, six-feet wide, to the sidewalk. Of these 13 elms, quired pits, like those on Prospect street, to be excavated he rock, and filled with good loam. Incidental to this k the springs of water discharging into the gutter have n availed of, as heretofore, as a means of transporting the plus earth in this bank to the depression on the northwest ner of St. Ronan street, below. In this manner, at no other than the labor of throwing the earth down upon the et, in ridges parallel to the gutter, in which the running er was confined, the larger portion of this bank has been oved. By simply planting willow cuttings thickly in the bottom, which catch and retain leaves and twigs, so much his washed earth has been deposited by the spent waters a low dam beyond has sufficed to retain the rest, and the er has passed off comparatively clear into the drains.

A few additional trees have been set out on the northeast ion of the Observatory grounds.

he construction by the city of the sewer in Canner street, n Whitney avenue westward to the line of the proposed nsion of Hillhouse avenue, has involved a large expense it is an improvement of corresponding value to the perty.

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bout the middle of January the Observatory received from ctor O. Struve, of the Observatory of Pulkowa, a list, espe- y calculated for this Observatory, of 90 stars whose occul- ns during and immediately before and after the total se of the Moon, to take place January 28, 1888, it was d we would be able to observe. Only a small number of ist could be observed with our eight-inch equatorial, and this work preparation was made by the Secretary under lirection of Dr. Elkin, and with his assistance and that of Hall, both of these gentlemen being prevented from under- ng these observations by their Heliometer work. Dr. n prepared the reduced list and checked the positions— h had been calculated for the position of the Atheneum, ne college campus, whose latitude and longitude are given ll the Nautical Almanacs yet issued, as those of Yale

Observatory. Semi-circular disks of dull black paper wer inserted in the focal plane of the eye-pieces to cut off all bu the small segment of the moon's disk, where immersion c emersion was to take place. Mr. W. W. Ellsworth called th settings and times, and recorded the observations. Th thermometer stood at $-2°$ Fahr. The clamp and slow motio in declination were disordered and were disconnected, an the moon followed entirely by hand. Until about $11^h$ 40 G. M. T., the moon was only occasionally glimpsed throug thin clouds. When these cleared away the edge of the moo was of a bright copper red, and its light too bright for th observation of the fainter stars of the list. Only fou observations were made, and these so unsatisfactory c account of the light and clouds, that it was not deeme worth while to communicate them to Director Struve.

The contributions to the Library of the Observatory durin the year ending June 1, 1888, have been as follows:

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## THE THERMOMETRIC BUREAU.

Mr. Peck has continued to make the comparisons of thermometers, and has introduced appliances for expediting his work, while securing greater accuracy in reading.

The general improvement noted last year in the accuracy of clinical thermometers received for comparison is still maintained. While these are, for each maker, presumably his best work, it is quite probable that the entire manufacture shares in the improvement, so that the usefulness of the Bureau is not justly measured by the mere number of instruments which pass through our hands. In the number certified there has been an increase of 1012 over last year and of 844 over the largest previous annual number, as shown by the following table.

Instruments received for certification during the years ending

| | |
|---|---|
| June 1, 1881, | 1,946 |
| June 1, 1882, | 4,533 |
| June 1, 1883, | 5,324 |
| June 1, 1884, | 6,392 |
| June 1, 1885, | 5,717 |
| June 1, 1886, | 6,355 |
| June 1, 1887, | 6,224 |
| June 1, 1888, | 7,236 |
| Total, | 43,727 |

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 7, 1888.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—Since my last report the series of observations on the parallaxes of the ten stars of the first magnitude in the Northern Hemisphere has been brought to a close. It may seem worth while to mention in brief here the results arrived at, in advance of their detailed publication in our Transactions. They are as follows:—

| Star. | Parallax. | Prob. Error. | No. of Comp. stars. | No. of obs. | Proper Motion. |
|---|---|---|---|---|---|
| $\alpha$ Tauri, | +0."116 | ±0."029 | 6 | 64 | 0."202 |
| $\alpha$ Aurigae, | +0.107 | 0.047 | 2 | 16 | 0.442 |
| $\alpha$ Orionis, | —0.009 | 0.049 | 2 | 16 | 0.022 |
| $\alpha$ Canis minoris, | +0.266 | 0.047 | 2 | 16 | 1.257 |
| $\beta$ Geminorum, | +0.068 | 0.047 | 2 | 16 | 0.628 |
| $\alpha$ Leonis, | +0.093 | 0.048 | 4 | 15 | 0.255 |
| $\alpha$ Bootis, | +0.018 | 0.022 | 10 | 89 | 2.287 |
| $\alpha$ Lyrae, | +0.034 | 0.045 | 2 | 30 | 0.344 |
| $\alpha$ Aquilae, | +0.199 | 0.047 | 4 | 16 | 0.647 |
| $\alpha$ Cygni, | —0.042 | 0.047 | 4 | 16 | 0.010 |

The probable errors here given include an estimation of the probable *systematic* error of the measures, derived from the agreement of the independent results from the several pairs of comparison stars where more than one such has been employed. They are therefore considerably larger than those generally assigned to such results, which, as a rule, only take into account the mere *casual* error of observation.

It will be seen on inspection of the table that of the ten stars six may be said to give indications of a measurable parallax, but in only two cases are the values in any degree remarkable. These are those for $\alpha$ Canis Minoris and $\alpha$ Aquilae, and it is worth while to note that they confirm closely results of former investigators, namely those of Auwers and Wagner on Procyon, which gave +0."240 ±0."029 and +0."299 ±0."038 respectively, and that of W. Struve at Dorpat on Altair, which gave +0."181 ±0."094. On the other hand my next two largest results, those for Aldebaran and Capella do not confirm the large values found by O. Struve at Pulkowa, which were +0."516 ±0."057 and +0."305 ±0."043. In the case of the former star I am, however, in close agreement with Hall at Washington,

who found +0.″102 ±0.″030, and there seems to be but little doubt that the Pulkowa value is largely in error. There have been no results of any importance derived hitherto for Pollux and Regulus, the remaining two of the six stars where the effect of parallax is at all sensible.

Of the four stars where the parallactic displacement has been inappreciable, Arcturus, with its large proper motion of over 2,″ second only to that of $\alpha$ Centauri in all of the 200 brightest stars down to the fourth magnitude, is especially noteworthy. The minuteness of the parallax is beyond doubt, depending as it does on five pairs of comparison stars, all in reasonable agreement, and it cannot be considered as seriously at variance with the results previously obtained by Peters and Johnson, +0.″127 ±0.″073 and +0.″138 ±0.″052 respectively, when their liability to systematic error is duly taken into account. For $\alpha$ Orionis and $\alpha$ Cygni, in view of their extremely small proper motions, the insensibility of their parallaxes is not surprising. The Yale result for $\alpha$ Lyrae, however, does not fall in well with those which have been hitherto deduced for this star. If we commence at the epoch of W. Struve and neglect the earlier attempts to find the absolute parallax, we have the following list of values :—

| | | |
|---|---|---|
| W. Struve at Dorpat, 1837–40, | +0.″261 | ±0.″025 |
| Peters at Pulkowa, 1842, | 0.103 | 0.053 |
| O. Struve at Pulkowa, 1851–53, | 0.147 | 0.009 |
| Johnson at Oxford, 1854–55, | 0.154 | 0.046 |
| Brünnow at Dublin, 1868–69, | 0.212 | 0.010 |
| Brünnow at Dublin, 1870, | 0.188 | 0.033 |
| Hall at Washington, 1880–81, | 0.134 | 0.0055 |

from which a parallax of about +0.″17 would seem well assured. The pair of comparison stars used here is very symmetrical and so large a value would seem incompatible with the Heliometer measures ; I hope, however, to be able to trace the discordance to its source.

In planning this work the object in view was the determination of the average or mean parallax of the stars of the first magnitude, and in pursuance of this I may state that the mean of the 10 values above given is

+0.″085 ±0.″015,

to which should probably be added +0.″004 as the probable parallax of the comparison stars which are in the mean of about the eighth magnitude, giving

$+0.''089 \qquad \pm 0.''015$

for thê result sought for. I do not, however, in view of the wide range of distance implied by the values of the above table, feel at all certain that this result may be taken as a measure of the average distance of the stars in question, and at all events it must be considered only as provisional and partial until it can be combined with the result for the first magnitude stars of the Southern Hemisphere, now in course of determination by Dr. Gill. At the same time I might draw attention to its near coincidence with the values derived by Gyldén (0.''084) and Peters (0.''102)—without, however, wishing to lay too much stress on this agreement.

The Heliometer is now being employed in a triangulation of the stars in the vicinity of the North Pole. Early in the year Prof. Pickering, of Harvard, applied to us to determine the relative places of a few stars to serve as fundamentals for a catalogue of the stars within 1° of the Pole by photographic methods. I have concluded to enlarge the plan originally laid out for this purpose, and am now observing 24 stars within 100′ of the Pole, nearly all that are measurable with the Heliometer in that area. The work is well under way, but as a considerable portion of the months of October, November and December are to be devoted to the joint observation with Dr. Gill of the extremely favorable opposition of Iris for a determination of the solar parallax, it may not be completed before next year.

Mr. Hall has been steadily occupied with the reduction of his measures on Titan, which is now approaching completion. In this connection he has made an extensive series of measures on the division errors of the parts of the scale in use therefor. He has also taken up for investigation of their parallaxes the stars 6 B. Cygni and 18115/22 Lalande, both of which present especial interest.

The series of measures of the Sun's diameter has been continued, a special research having been undertaken on the influence of different apertures upon the same, and upon the scale value. We have also made some measures of the diameter of Mars at its late opposition and of various double stars.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1888–89, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

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# REPORT.

YALE UNIVERSITY, June 24, 1889.

*To the President and Fellows of Yale University:*

GENTLEMEN:—We herewith present to you the Report of the Secretary of the Observatory, and that of the Astronomer in charge of the Heliometer.

The time service has been throughout the year under the care of Mr. Hall the Assistant Astronomer.

The Board expresses its sense of the loss which the Observatory suffered in the death, January 14, of one of our number, Jacob Campbell, Esq., of New York City. Mr. Campbell was one of the Trustees selected by Mr. Winchester in 1872, and upon the transfer of the Observatory to the College, Mr. Campbell was made one of the Board of Managers. Whenever his health and business permitted he attended the meetings of the Trustees and of the Board, and he was deeply interested in the plans and work of the Observatory. For the development of these he made repeated and generous donations.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE OBSERVATORY, June 18, 1889.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report that during the year ending June 1, 1889, improvements of the Observatory grounds have been effected as follows:

1. In the south sidewalk of Highland street elm trees have been planted, in continuation of the former year's planting, from Prospect street to St. Ronan street, excepting at three points where a little blasting will be necessary, to be done as the season permits.

2. In the west sidewalk of St. Ronan street a short distance south of Highland street, five elm trees have been planted—all that the present grade of the ground would justify. Since the season passed for planting, the city has been doing something toward the grading of St. Ronan street, by removing all the earth, down to the rock, and between curb lines, from that portion of the street extending about five hundred feet north from Canner* street, to fill that portion next south of Canner street. At about midway from Canner street to Highland street there will be a further cut, through rock, of two or three feet, gradually lessening in either direction for an average distance of one hundred feet or more. St. Ronan street is thus opened to travel from Canner street southward to its intersection with Lawrence street. A fill of about 800 yards, is thus made necessary in the lot on the southwest corner of Canner and St. Ronan streets. Our side of St. Ronan street, northward from Canner street, will present about 900 feet of beautifully situated and well drained lots, in every way desirable for building purposes, containing handsome well-grown beeches, oaks and other native forest trees, and within 500 feet of the Whitney Avenue street cars. The cut which the city has made will facilitate the extension of the line of shade trees in the west sidewalk, which I hope to complete in the

*I here and in recent reports, conform to the city's official spelling of this name, as it is pronounced, rather than adhere, as in earlier reports, to the original spelling.

coming Fall and Spring, thus attaining the aggregate of 6,000 feet of frontage planted with shade trees from the beginning in 1883.

3. On the north side of Canner street the sidewalk has been graded for the full width in that portion which required excavation, the city taking all the earth which we could spare to replace that washed from the adjacent street, and to raise the grade of the street eastward. About 300 yards of filling will be required to complete this sidewalk to St. Ronan street, when the entire frontage will present an attractive appearance.

4. Within the Observatory reservation a few additional trees have been planted in the northwest corner, and some of former plantings which did not thrive have been replaced. A limited nursery of small sugar and Norway maples, oaks, elms, etc., has been planted with regard to our future requirements.

The number of visitors to the Observatory has been larger than formerly, probably because it has been more frequently practicable than in working Observatories generally, to exhibit the various objects of popular interest. No record has been kept of such occasions, nor of the rarer, yet not infrequent, calls of astronomers of note from all parts of the world.

The contributions to the Library of the Observatory during the year ending June 1, 1889, have been as follows:

| | |
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In addition to the foregoing gifts to the Library, we have received as follows:

From Messrs. Sardy, Coles & Co., New York City, agents for the patentees and makers, one gilt "Immisch" registering clinical thermometer, illustrating the method of construction and action.

From the Lick Observatory, a glass positive of the solar eclipse of January 1, 1889, taken by Prof. Barnard, which beautifully exhibits the equatorial bands and polar radiations of the corona. This desirable acquisition came to us through Dr. Elkin upon his return from California.

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## THE THERMOMETRIC BUREAU.

The comparison of thermometers has continued to be made by Mr. C. B. Peck. The number received for verification during the year ending June 1, 1889, was 7,475, being 249 in excess of the preceding, our maximum, year.

It is perhaps well to call public attention to the fact, not new, but continually overlooked, that the most accurate thermometers may be made to give false testimony, by misinterpretation of their language.

Although every certificate issued from this Observatory, for other than clinical thermometers, contains a statement of the only conditions under which the correction therein given can be truthfully applied, we are continually called upon to explain, especially in the case of high temperature thermometers, that when only the bulb is immersed in a liquid of high temperature, the indicated temperature is too low by an amount depending upon the number of degrees of the mercury in the cooler stem and the difference between the temperatures of the bulb and stem. We have been called upon to show frequently that this error, which is independent of any correction due to the thermometer, may be as much as 8° or 9° in the case of high temperature oils, as their temperatures are generally measured. A simple remedy for this indefiniteness of measurement would seem to be a special form of thermometer in which nearly all the mercury should be immersed. As a result of considerable correspondence with parties interested in the accuracy of measurements of this sort, it was suggested

that this Observatory should be represented at a convention held last January, but as it did not appear that the expense to the Observatory would be covered by the compensation likely to be received from this class of work, and the funds were wanting to enable us otherwise to render this public service, no encouragement was given to tender the proposed official invitation.

Of the same nature is the correction of possibly $0.^\circ 1$ to be applied to clinical thermometers of the "Indestructible Index" form, when the detached column of mercury constituting the index is quite long (expressed in degrees) and is read after removal to a much cooler atmosphere. Our comparisons require us to take precaution on this account in the colder days of winter; but any notice of the matter or instructions on the precautions to be taken in using these instruments have been deferred until a new edition of our circular of instructions and conditions should appear to be called for, and this the more readily because the probable error on this account does not exceed the probable error of reading.

Very respectfully,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE OBSERVATORY, June 10, 1889.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—During the summer months of 1888 I completed the measures with the Heliometer for the triangulation of the region near the North Pole. The reductions of these measures are well advanced, but as the final adjustment involves the determination of the 48 coördinates of the 24 stars from 144 of their observed intermutual distances, it may require some considerable time yet.

In October we commenced the series of observations on the minor planet Iris in conjunction with the observatories at the Cape and at Leipzig. The autumn months were unfortunately by no means as favorable as usual and we only secured measures on 34 of the 65 planned nights. We undertook at the same time a further series for the diurnal parallax of the planet and the following table shows the total amount of observations obtained, each set consisting of 16 pointings:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Elkin: | Eastern Observations: | 86 | Sets | on | 29 | Nights. |
| | Western " | 23 | " | " | 10 | " |
| Hall: | Eastern " | 31 | " | " | 17 | " |
| | Western " | 28 | " | " | 18 | " |

We have undertaken here the discussion of the whole series of measures, and have made some progress in comparing the meridian observations of the planet and comparison stars, as well as in the reduction of the Leipzig and Yale Heliometer measures, the former having been kindly forwarded in all detail by Prof. Bruns.

We are now commencing a similar series on the planet Victoria to continue through until September and a third series on Sappho is to occupy us in September and October. As in addition to the Heliometers used for Iris, those at Bamberg and Göttingen will probably coöperate this year, the three series together will doubtless furnish a very accurate value of the Solar Parallax.

The Heliometer has also been employed in some supplementary series on the parallaxes of the Northern brighter stars,

Mr. Hall having taken up Procyon and $\alpha$ Aquilae and myself Vega and $\alpha$ Leonis.

During the winter Mr. Hall completed the reductions of his work on the orbit of Titan, the results of which are in very satisfactory agreement with those of Bessel and Hermann Struve. The value found for the mass of Saturn is 1: 3500.5 of the Solar mass, Bessel's revised value being 1: 3502.5 and Struve's 1: 3498.

I myself spent the winter months in the West, observing the total solar Eclipse of Jan. 1, 1889, at Winnemucca, Nevada, under very favorable circumstances. I used the finder of the Heliometer for a general view of the Corona, and with the low power and large field of about 4° I could trace the equatorial streamers to a distance of about 100′ on either side from the limb. I devoted a part of the time near the beginning and end of totality to a careful scrutiny of a small portion of the outer rays of the corona with a view of detecting any possible rapid changes in the same, but during the 90 seconds of observation and in the portion I looked at, nothing of this nature occurred. I also had the good fortune to enjoy fine weather during a visit to the Lick Observatory, where by the courtesy of Prof. Holden and his staff, I had unlimited opportunities for forming a very high estimate of the powers of their magnificent 36 inch refractor, both for purely visual and for photographic purposes. In particular, I was enabled to do some measuring with the measuring engine of the Observatory, on some photographic plates of the Pleiades, most kindly taken especially for me with the large telescope. The comparison of the results with the star-places derived with the Heliometer at Yale afforded a most satisfactory proof of the accuracy of these latter, and of the immense possibilities of the photographic methods for micrometric work. I may add that in a paper sent to Dr. Gould for publication in the Astronomical Journal, where I have compared the results derived by him from Mr. Rutherfurd's Pleiades photographs with the Heliometer work, the extremely high accuracy attainable by photography is also very apparent.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1889–90, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

Rev. TIMOTHY DWIGHT, D.D., LL.D., *President.*
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## OFFICERS.

ROBERT BROWN, M.A., *Secretary.*
WILLIAM L. ELKIN, PH.D., *Astronomer in charge of the Heliometer.*

# REPORT.

YALE UNIVERSITY, June 23, 1890.

*To the President and Fellows of Yale University:*

GENTLEMEN :—The Board of Managers herewith transmit the reports of Mr. Brown the secretary of the Observatory, and of Dr. Elkin, the Astronomer in charge of the Heliometer. The time service was in charge of Dr. Hall until he left us to accept a position in the Observatory at Washington. Since that time the clocks and the time signals have been under the care, first of Mr. John Whitmore, and later of Mr. B. W. McFarland.

Two members of the Board have died during the year, Professors Elias Loomis, and Chester S. Lyman. The Board desires to express its deep sense of the value of the services which these two men have rendered to the Observatory and to science, and of our loss by their removal from us. They were selected by Mr. Winchester to be Trustees of the institution at its first inception. He relied upon them for advice and assistance in giving wise direction to his generous designs for the advance of the Science of Astronomy. During eighteen years they have attended the meetings of the Trustees and of the Board, and by their counsel and labors have done what they could to build up the Observatory, and make it efficient. Professor Loomis moreover has shown his enduring interest in the Observatory by making it by will the recipient of his large fortune. After making liberal provision for his two sons he has given the remainder of his estate to form a *Loomis Fund* the income of which is to provide for the payment of the salaries of observers and computers in the Observatory, and for the expenses of publication of astronomical memoirs. The distinguished scientific work of his life will thus, we may trust, be continued through the future centuries of years.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE OBSERVATORY, June 18, 1890.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report that during the year ending June 1, 1890, the improvements of the Observatory grounds have progressed as follows:

1. The line of shade trees (elms) on our Highland street frontage has been completed.

2. Nineteen additional elms have been placed in the west sidewalk of St. Ronan street between Canner and Highland streets, leaving three required to complete that frontage when the grading is completed.

3. Considerable progress has been made in grading the west sidewalk of St. Ronan street, at which we are still at work. A large portion of the frontage on the east side, opposite our tract, has recently been sold, on which a handsome dwelling is now in process of construction, and others are contemplated, to be erected during the next year or the following.

4. Fence posts have been set on Highland, St. Ronan, and that part of Canner street where they were lacking, except near St. Ronan street, where further grading is first required. A few remain to be set on Prospect street, where hard rock requires blasting, and this shall be done as opportunity offers.

5. Within the Observatory lot, twenty-six young Norway spruces, contributed by Dr. Elkin, have been planted, here and there, with regard to future effect.

6. A few flowering and ornamental shrubs have been planted near the Observatory—all that could be done in this way with our small force, without delaying more important improvements.

At the death of Prof. Elias Loomis, by his will, the Observatory came into possession of a very fine portrait of himself by Mrs. H. A. Loop, painted in 1882, which will hang, for the present, in the office of the Observatory. As a gift from Mr. Henry B. Loomis and otherwise the Observatory possesses

valuable mementoes of Prof. Loomis:

The three thermometers long used by him:

B. Pike & Son, New York, Meteorological—with extra long bulb.

L. Casella, "verified" Maximum No. 2495.

L. Casella, "verified" Minimum No. 1791.

The writing desk at which his later work was done, and some of his book cases.

Before his death Professor Loomis had ordered that shelves be constructed at his expense for his books at the Observatory, which order had been partially complied with. Of his library bequeathed to the Observatory, after selections for the University Library, there has come to us the equivalent of 1900 volumes—estimating miscellaneous pamphlets, maps, etc., at the average thickness of books of the corresponding fold. Of the scientific serials many are complete; many lack a few volumes, and may be said to be nearly complete; and some, lacking more may be classed as incomplete, while the proportion in our possession of volumes issued is nevertheless quite considerable. It has not been practicable to make a full catalogue of this valuable bequest, but the following titles indicate, in a measure, its general character.

SERIALS.

American Journal of Science and Arts.

Transactions and Proceedings of the American Academy.

Transactions and Proceedings of the American Philosophical Society.

Memoirs and Monthly Notices of the Royal Astronomical Society.

Astronomische Nachrichten.

Philosophical Transactions of the Royal Society, London, 1801–56.

Transactions of the Cambridge Philosophical Society. Vols. I to XI.

Reports of the British Association for the Advancement of Science.

Greenwich Observations (incomplete).

American Journal of Mathematics.

Proceedings of the American Association for the Advancement of Science.

Mitchell's Sidereal Messenger.

Berliner Jahrbuch (incomplete).
Science.
Smithsonian Institution Reports.
Annals of Philosophy and Philosophical Magazine (incomplete).
Annales de l'Observatoire Physique Central de Russie—1854–64.
Wolf's Vierteljahrsschrift.
Reports of the U. S. Chief Signal Officer.
Reports of the U. S. Chief of Engineers.
Gould's Astronomical Journal.
Nature.
Nautical Almanac (Greenwich).
American Ephemeris and Nautical Almanac.
Philosophical Society, Glasgow (incomplete).
Dun Echt Observatory Publications.
Memoirs of the Connecticut Academy.
Leiden Observatory—Annalen.
Albany Institute—Transactions.
Meteorological Publications—Deutsche Seewarte, Hamburg.
- St. Petersburg Observatory.
- Oficina Meteorológica Argentina, Buenos Aires.
- K. K. Central Anstalt, Vienna.
- Government of India—Calcutta and Bombay.
- British Government—Home and Colonial.
- Carlo Alberto College, Moncalieri.
- Norwegisches Meteorologisches Institut, Christiania.
- Quarterly Journal of the Royal Meteorological Society, London.
- Oesterreichische Gesellschaft, Zeitschrift. Vienna.
- U. S. Weather Maps, bound and unbound.
- U. S. International Weather Maps.
- Symons's Meteorological Magazine.
- Scottish Meteorological Society.
- Tokio Daigaku.

BOOKS.

Bowditch LaPlace—Mécanique Céleste.
Pingré—Cométographie.
Montucla—Histoire des Mathématiques.
Sir J. Herschel—Cape Results.

Vega—Thesaurus Logarithmorum Completus.
British Association Catalogue.
Markree Catalogue.
Glasgow Catalogue.
Struve—Mensuræ Micrometricæ.
Halma-Ptolémée—Almageste.
Beer und Mädler. Der Mond.
LaLande—Bibliographie Astronomique.
Comte—Philosophie Positive.
Fourier—Théorie de la Chaleur.
Watson—Theoretical Astronomy.
Bayer—Uranometria.
Vince—Astronomy.
Pearson—Astronomy.
Gehler—Physikalisches Wörterbuch.
Bessel—Astronomische Untersuchungen.
Gauss—Theoria Motus.

The ordinary contributions to the Library, by donation and exchange, during the year, have been as follows:

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| Ann Arbor. American Meteorological Journal, Vol. VI, May, 1889–April, 1890. 8°. *Ann Arbor*, 1889–90. | Prof. H. A. Newton. |
| H. G. van de Sande Bakhuyzen. Beschreibung eines Apparats zur Bestimmung des absoluten persönlichen Fehlers bei Durchgangsbeobachtungen nebst Mittheilung der damit erhaltenen Resultate. 4°. *The Hague* [1889]. | The Author. |
| ——et Bassot. Détermination de la Différence de Longitude entre Leyde et Paris. 4°. *Paris*, 1889. | H. G. van de Sande Bakhuyzen. |
| W. Beebe and A. W. Phillips. The Orbit of Swift's Comet 1880, V; determined by Gibbs' Vector Method [Astr. Jour., Nos. 207–8]. 4°. *Cambridge* [1889]. | The Authors. |
| Berkeley. Annual Report of the Secretary to the Board of Regents of the University of California, for the year ending June 30, 1889. 8°. *Sacramento*, 1889. | The University. |

Smithsonian Institution. Frank H. Bigelow. The Solar Corona, discussed by Spherical Harmonics. 4°. *Washington*, 1889.

The Academy. Bologna. R. Accademia delle Scienze dell' Instituto di——. Memorie, Serie IV, Tomo VIII. 4°. *Bologna*, 1888.

—— —— —— ——Tomo IX. 4°. *Bologna*, 1889.

—— —— ——Note sur les derniers progrès de la question de l'heure universelle. 8°. *Bologna*, 1888.

—— Boston. American Academy of Arts and Sciences. Proceedings. New Series. Vol. XV, Pt. II. 8°. *Boston*, 1888.

The Publishers. Buffalo. Medical and Surgical Journal. June, 1889–May, 1890. 8°. *Buffalo*, 1889–90.

The University. Cambridge, England. Thirty-fifth Annual Report of the Library Syndicate. 4°. *Cambridge*, 1889.

The Observatory. ——Mass. Harvard College Observatory Annals. 4°.

Vol. XVII, No. IX. Meridian Circle Observations of Close Polar Stars. —— ——

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—— —— —— ——Vol. XXI, Part I. Observations of the New England Meteorological Society in the year 1888. *Cambridge*, 1889.

—— —— —— ——Vol. XXII. Meteorological Observations made on the Summit of Pike's Peak, Colorado, January, 1874, to June, 1888, under the direction of the Chief Signal Officer, U. S. A. *Cambridge*, 1889.

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| Cambridge, Mass. The Bruce Photographic Telescope. 4°. *Cambridge*, 1889. | The Observatory. |
| —— ——Henry Draper Memorial. Fourth Annual Report of the Photographic Study of Stellar Spectra. 4°. *Cambridge*, 1890. | —— |
| —— ——Forty-fourth Annual Report of the Director. 8°. *Cambridge*, 1890. | —— |
| —— ——Bulletin No. 62 of the New England Meteorological Society. 4°. *Cambridge*, 1889. | —— |
| Chapel Hill. Journal of the Elisha Mitchell Scientific Society. Vol. VI, Parts 1 and 2. 8°. *Raleigh, N. C.*, 1889–90. | The Society. |
| Albert E. Church. Elements of Descriptive Geometry with its Application to Spherical Projections. 8°. *New York*, 1864. | Prof. F. E. Loomis. |
| Charles Davies. Treatise on Shades and Shadows and Linear Perspective. 8°. *New York*, 1859. | —— |
| R. Dedekind. Vorlesungen über Zahlentheorie von P. G. Lejeune-Dirichlet. 8°. *Braunschweig*, 1863. | —— |
| Denver. Publications of the Chamberlin Observatory of the University of Denver. No. 1. 8°. *Denver*, 1889. | The Observatory. |
| Charles L. Dodgson. Elementary Treatise on Determinants. 8°. *London*, 1867. | Prof. F. E. Loomis. |
| W. Döllen. Stern-Ephemeriden auf das Jahr 1890. 8°. *St. Petersburg*, 1890. | The Author. |
| Dublin. Scientific Transactions of the Royal Dublin Society. Vol. IV, (Series II,) III. Observations of the Planet Jupiter . . at Birr Castle Observatory, Parsonstown. By Otto Boedicker. 4°. *Dublin*, 1889. | The Society. |
| A. J. Dubois. Science and Miracle. 8°. *New Haven*, 1889. | The Author. |
| Dun Echt Observatory Circulars. Nos. 171–179 (and last). 8°. *Dun Echt*, 1889–90. | The Observatory. |
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| Wm. L. Elkin. Comparison of Dr. Gould's Reductions of Mr. Rutherford's *Pleiades* Photographs with the Heliometer Results. [Astr. Jour., No. 197]. 4°. *Boston*, 1889. | The Author. |

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| The Author. | Folke Engström. Bestämning af Lunds Observatorii Polhöjd [Aftryck ur Lunds Univ. Årsskrift, Tom. XXV]. 4°. *Lund*, 1889. |
| Prof. F. E. Loomis. | Carl Friedrich Gauss. Werke. Band 2, 3 und 4. 4°. *Göttingen*, 1863, '66 and '67. |
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| —— | Greenwich. Royal Observatory. Nautical Almanac and Astronomical Ephemeris for the year 1874. 8°. *London*, 1870. |
| —— | —— —— ——for the year 1875. 8°. *London*, 1871. |
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| —— | ——Royal Observatory. Astronomical and Magnetical and Meteorological Observations made in the year 1887, under the direction of W. H. M. Christie. 4°. *London*, 1889. |
| —— | —— ——Rates of Chronometers on Trial for purchase by the Board of Admiralty. 4°. *London*, 1889. |
| —— | —— ——Rates of Deck Watches on Trial for purchase by the Board of Admiralty. 4°. *London*, 1889. |
| —— | —— ——Assumed Mean Right Ascensions of Clock Stars with the corrections to the R. A. of the Nautical Almanac for 1890.0. 4°. *London*, 1889. |
| —— | —— ——Ten Year Catalogue of 4059 Stars for 1880. 4°. *London*, 1889. |
| —— | —— ——(a) Recomputation of the position of the Ecliptic from Observations of the Sun, in the years 1877–1886. (b) Corrections to Refraction of Stars, Sun, Moon, and Planets, for revised readings of the exterior thermometer and of the barometer, in the years 1877–1886. 4°. *London*, 1889. |

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| Charles F. Hall. Narrative of the Second Arctic Expedition. 8°. *Washington*, 1879. | Prof. F. E. Loomis. |
| Havana. Observaciones Magnéticas y Meteorológicas del Real Colegio de Belen de la Compañia de Jesus. 4°. [To Dec., 1887.] *Havana*, 1889. | The College. |
| Haverford College Observatory. Micrometrical Measurements of Double Stars and other Observations, under the direction of F. P. Leavenworth. ——— [1889]. | The Observatory. |
| Helsingfors. Beobachtungen von Cometen angestellt auf der Sternwarte zu ——, im Winter und Frühjahr 1885–1886, von Anders Donner. [Abdruck aus Acta Soc. Sci. Fennicae, Tom. XVII.] 4°. *Helsingfors*, 1888. | ——— |
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| Kasan. Observations des Étoiles de la Zone entre 75° et 80° de déclinaison boréale. Sous la direction de Marian Kowalski. 4°. *Kasan*, 1887. | ——— |
| S. P. Langley. The Temperature of the Moon. 4°. *Washington*, 1889. | The Author. |
| Liverpool Astronomical Society. Journal for Feb., 1889. Report of the Meteoric Section. *Liverpool*, 1889. | Prof. H. A. Newton. |
| Lund. Observations des Étoiles de la Zone entre 35° et 40° de déclinaison boréale—Réduites à l'équinoxe moyen de 1875.0 par N. C. Dunér et Folke Engström. Tome II, 1 et 2. 4°. *Lund*, 1889. | The Observatory. |
| Madrid. Memorias de la Real Academia de Ciencias Exactas, Físicas y Naturales. Tomo XIII, Partes 2 y 3. 8°. *Madrid*, 1888–89. | The Academy. |
| Manchester. Literary and Philosophical Society. Memoirs and Proceedings. Fourth Series. Vol. I. *Manchester*, 1888. | The Society. |
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| —— | —— ——Ephemeris of the Satellite of Neptune, 1889–90. 8°. *London*, 1889. |
| —— | —— ——On the close Conjunction of Mars and Saturn, Sept. 19, 1889. On the Eclipse of Jupiter by Saturn and its Ring System, Nov. 1–2, 1889. 8°. *London*, 1889. |
| —— | ——Ephemeris for Physical Observations of the Moon, 1889 (July 1) to 1890 (Jan. 1). 8°. *London*, 1889. |
| —— | —— ——Ephemeris for Physical Observations of Jupiter, 1890. 8°. *London*, 1890. |
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| The Author. | Eliakim H. Moore. Algebraic Surfaces of which every Plane Section is unicursal in the light of N. Dimensional Geometry. 4°. |
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| The Publishers. | New York. The Jewelers' Circular and Horological Review, June, 1889–May, 1890. Vol. XX, No. 5, to Vol. XXI, No. 4. 4°. *New York*, 1889–90. |
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| —— ——Anno CCXC (1888–89). Nuova Serie. Vol. V. *Padua*, 1889. | The Academy. |
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| —— ——Extrait à l'usage des Écoles d'Hydrographie et des Marins du Commerce, pour l'an 1891. 8°. *Paris*, 1889. | —— |
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| ——Annuaire de l'Observatoire Municipal de Montsouris, pour l'an 1889. 12°. *Paris*, 1889 | The Observatory. |
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| —— ——Astronomische Beobachtungen in den Jahren 1885, 1886 und 1887, enthaltend Originalzeichnungen des Mondes. L. Weinek. Appendix zum 46, 47 und 48 Jahrgang. 4°. *Prague*, 1890. | —— |

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### THE THERMOMETRIC BUREAU.

The comparison of thermometers has continued to be made by Mr. C. B. Peck.

The number received for verification during the year ending June 1, 1890, was 8569, being 1094 in excess of the preceding, our previous maximum, year.

Very respectfully,

ROBERT BROWN,
*Secretary of the Observatory.*

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## REPORT OF DR. ELKIN.

YALE OBSERVATORY, June 10, 1890.

*To the Board of Managers of the Observatory:*

GENTLEMEN :—During the summer and autumn of 1889 the work with the Heliometer was principally directed to the observation of the minor planets, Victoria and Sappho, in connection with the observatories having a similar instrument at the Cape of Good Hope and at Leipzig, Göttingen and Bamberg, Germany. We secured complete series of measurements as follows:

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| on Victoria: | Elkin | 37 | Series. |
| | Hall | 17 | " |
| on Sappho: | Elkin | 15 | " |
| | Hall | 18 | " |

The fewer number of observations of Victoria obtained by Dr. Hall is due to his having accepted an appointment at the Naval Observatory at Washington which required his presence there after the beginning of August. By the kind offices of Prof. Eastman, however, Dr. Hall was detailed to New Haven

for the Sappho work, so that during that period no favorable opportunity was allowed to escape. Before leaving, Dr. Hall saw through the press his paper on the Orbit of Titan and Mass of Saturn, published and distributed as Part I. of our Transactions.

The reductions of these measures of Victoria and Sappho have been kept well forward and require now only a final revision. For the Iris series in 1888 also, our own work—and that at Leipzig and Oxford—has been fully reduced and considerable progress made in the computations necessary for a deduction of the Solar parallax.

For the full utilization of all the measures made on Victoria, Dr. Gill has proposed a heliometric triangulation of the comparison stars. Mr. F. L. Chase has taken up the study of work with the heliometer and will carry out this measurement this summer.

Since the completion of the work on the minor planets I have taken up again the observations on the parallaxes of the first magnitude stars in the Northern hemisphere with the intention of carrying out the work as I had originally planned it, securing at least three independent results for each of the ten stars. It appeared to me that the advantages of the heliometer for these bright stars were such as to make it well worth while to pursue the investigation and strengthen the results already obtained, without the fear of their being immediately supplanted by those of the photographic method of observation. It seems difficult to resist the conviction that this latter method will prove incontestably superior for all but the very brightest stars. About one third of the proposed continuation has been secured.

The computations of the triangulation of the stars near the North Pole made in 1888, are in an advanced state though not yet quite completed.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1890–91, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

Rev. TIMOTHY DWIGHT, D.D., LL.D., *President.*
EDWARD M. REED, M A.
Professor HUBERT A. NEWTON, LL.D., *Secretary.*
WILLIAM W. FARNAM, M.A.
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Professor CHARLES S. HASTINGS, PH.D.

## OFFICERS.

ROBERT BROWN, M.A., *Secretary.*
WILLIAM L. ELKIN, PH.D., *Astronomer in charge of the Heliometer.*
FREDERICK L. CHASE, B.A., *Assistant.*

# REPORT.

Yale University, June 22, 1891.

*To the President and Fellows of Yale University:*

Gentlemen:—The Board of Managers herewith transmit the reports of Mr. Brown the Secretary of the Observatory, and of Dr. Elkin, the Astronomer in charge of the Heliometer. The clocks and the time signals have been throughout the year under the care of Mr. B. W. McFarland.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE OBSERVATORY, June 17, 1891.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report the following improvements and repairs made to the buildings and grounds of the Observatory during the past year:

### BUILDING.

The upper and lower halls and the south-east room on the first floor—the Reception Room and Office—and the bedroom above the latter have been tinted and papered for the first time. The bedroom has been carpeted and furnished for Mr. Chase's occupancy.

Absolutely necessary repairs have been made as follows:

1. The leaking roof of the main building has been patched.
2. All the tin roofs have been repainted.
3. The canvas-covered domes have been repaired and repainted.

### OBSERVATORY RESERVATION GROUNDS.

A six-inch sewer connection, four hundred and twenty-five feet in length, has been laid from the southeast corner of the present main building, and along its south side, to a point about six feet east of the south gate-post of the southern branch of Dr. Elkin's driveway, where it connects with the branch sewer to Dr. Adams' house.

### GROUNDS NORTH OF CANNER STREET.

The fifteen-inch drain pipe which was laid by the city under Canner street, when that street was graded, to receive the water which flows in the ravine through this lot from the northwest, we have extended one hundred feet up the ravine—laying the same carefully in cement. I recommend a further extension of four or five hundred feet, to be made whenever the prices of pipe and labor are most favorable.

The grading of the west sidewalk of St. Ronan street, which was under way at the date of the last report, has been prosecuted very nearly to completion. This street is seventy feet in width, of which eighteen feet on each side has been set apart for sidewalks and shade trees. The grade of the street is easy; from the center of Canner street, seventy-three feet above tide-water, rising, northward, four inches in one hundred feet for a distance of forty feet, thence eighteen inches in one hundred feet for a distance of five hundred feet, thence level for a distance of forty-five feet, thence descending eighteen inches in one hundred feet for a distance of five hundred and fifty-five feet to a point in Highland street. The middle point of our frontage (of about eleven hundred feet) is therefore about seven and a half feet above each end. The north end of our sidewalk required a fill of about two hundred and fifty feet long, and, at the deepest, eight or ten feet. But the land rises so rapidly from the street westwardly, that the excavation for a single cellar will probably fill the present depression to the grade of the sidewalk. In the next six hundred and fifty feet, southward, the surface rises rapidly to five or six feet above the established grade, falling again until at the southern end the last two hundred feet in length was from six to ten feet below the established grade. The sidewalk has been graded in such manner that across the fills the fence line has the regulation rise of nine inches above the curb line, but where the surface rises considerably the grade of the sidewalk, at the fence line, rises also to the height of thirty-six inches above the curb line. With the material thus excavated the fills at the two ends have been made, mainly; the top soil being reserved for the grass and for the trees. Of the eighteen feet in width, of the sidewalk, seven feet has been reserved for the walk, and the remaining eleven feet, rounded in section, has been put in grass, with a center line of twenty-six elm trees. For some of these trees the rock was blasted out eight or ten feet square and two and a half or three feet deep. There remains a gap of about sixty feet in length by about five feet in depth, to be filled at the south end, adjoining Canner street. The City Street Department having previously taken the surface of this street, which was above grade and easily removed, to another street or another portion of this street, has now or is about to undertake, as I am informed, the grading of the

street from curb to curb, involving a cut of about three feet in the middle third. When this has been done there will be immediately available for the market about eight hundred feet of frontage, about one-third of the way up the hillside and within five to eight hundred feet of the Whitney avenue line of street cars. In my judgment these lots should be laid out with a view to the preservation of a large proportion of the handsome forest trees which are scattered over four-fifths of the tract. And I think this end will best be attained by following Mr. Winchester's wisely expressed preference that the tract should be laid out in what is commonly called the "park style" in contradistinction from the strictly rectangular style which is found most convenient for city centers. In this manner the steep grades of the eastern slope may best be overcome, and some of the rougher features of the land, which it would be a great expense to remove, would contribute to the beauty of the whole, and the tract may be made to yield the largest sum to the designed endowment.

The contributions to the Library of the Observatory during the year ending June 1st, 1891, have been as follows:

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| —— —— ——1885. 4°. *Washington*, 1891. | —— |
| —— —— —— ——Appendix I. The International Astrophotographic Congress, and a visit to certain European Observatories and other Institutions. Report to the Superintendent by Albert G. Winterhalter. 4°. *Washington*, 1889. | |
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| —— —— —— ——Appendix III. The Solar Parallax and its Related Constants, including the Figure and Density of the Earth. Wm. Harkness. 4°. *Washington*, 1891. | —— |
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In addition to the foregoing there have been placed upon the Library table, shortly after publication, as loans, the following periodicals :—

By Professor Newton : "The Observatory"—for the past three years.

By Dr. Elkin : "Astronomische Nachrichten." "The Astronomical Journal." "Vierteljahrsschrift der Astronomischen Gesellschaft." "Science."

By others : "Nature." "American Journal of Science and Arts."

In the absence of any fund whatever for the increase of the Library, either by the purchase of books or by subscription to the absolutely necessary current literature, the great acceptability of these temporary provisions will be recognized at once. Through the Loomis bequest, the Library possesses complete or nearly complete sets of these periodicals down to within two or three years. The continuations loaned, as above, belong to series reaching far back, and to break these would in some cases be a damage out of proportion to the gain of the Observatory. Situated as we are a mile and a half from the College Library, such of these periodicals as are to be found there can be of little use to us, in the frequent momentary references which have to be made in the progress of our work. The income of an initial fund of about one thousand dollars, for the maintenance of subscriptions to the most essential astronomical periodical literature seems to be a desideratum requiring only to be known to be attained. It will be observed that our publications bring us a large number of exchanges, including some which are not exclusively Astronomical but which are very acceptable, and these exchanges are continually increasing. But there are many necessary publications which are not freely exchanged, and for these a further endowment fund is greatly needed, but can await the provision of that first named.

### THERMOMETRIC BUREAU.

Mr. Peck has continued to make the thermometer comparisons. The principal American manufacturers maintain their standard for small corrections. Perhaps a quality of the "Independent Index" form—not, however, essential—ought to be noticed in these reports: it is that of losing, more or

less easily the sustaining power of the "trap." We have often to reject instruments—not unfrequently to the extent of twenty per cent.—in which, *occasionally*, the index will drop, the greatest care being exercised, while in a larger number of instances, and at the same temperature, it will maintain its position as a maximum register. This quality has probably been generally recognized by makers and users, and not regarded as more serious than the permanent loss of the "short" index, which could, indeed, be restored, but with a liability to change in the corrections. Under unequal stress in the glass, from the mode of cooling after the production of the "trap," probably, a slight concussion will sometimes cause a minute fracture in the "trap" by which its sustaining power is lost. Recently three instruments were returned to us, which would not under any circumstances register: but two months previously, under repeated tests they did not fail to register; in one of them the microscope revealed a small loosened fragment of glass, just below the "trap," which must either have been detached after our previous examination, or, by its position, have assisted the trap at that time in the performance of its function; the other two instruments are assumed to have undergone a like fracture, although that was not demonstrated.

Mr. Peck also calls attention to the observation that some instruments of this form which register correctly when suddenly transferred to a temperature lower by ten degrees or more, will fail to register when the temperature is more gradually lowered, as by transfer to a medium only ten, or less, degrees cooler—or when left in a bath which is allowed to slowly fall in temperature. The cause of this is taken to be that in a particular construction of the "trap" a somewhat sudden contraction of the mercury near the "trap" may be required to overcome a cohesion of the mercury which is more effective than the resistance of the "trap." In many of these cases the preservation of the instrument in a horizontal position, where that is practicable, until the reading is made, will probably overcome the difficulty, exercising care that the index does not rise as in some cases it will, even against gravity.

Very respectfully,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 9, 1891.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—The work under my charge has progressed during the past year as follows:

In observational work with the Heliometer I have been engaged almost wholly in the continuation of the series on the parallaxes of the first magnitude stars in the Northern hemisphere. The scheme originally laid out has now been completed and furnishes for each of the ten stars three (for Arcturus, five) independent results. The reductions are also nearly finished and the final values will be very shortly ready for publication.

The triangulation of the comparison stars for Victoria according to the plan drawn up by Dr. Gill has been carried out by Mr. F. L. Chase, who secured some 450 measures of these stars during the months of June to October, 1890. Mr. Chase has also reduced the observations as far as it was advisable for us to do so here and the results have been communicated to Dr. Gill, along with the reduced results of our observations of Victoria and Sappho in 1889. Since February, 1891, Mr. Chase has been engaged in a triangulation of the principal stars in *Coma Berenices* and up to date about one-half of the proposed measures have been obtained. Mr. Chase has also used the 8-inch Reed Equatorial for the determination of places of Comet Zona (1890, iv) and several asteroids, the results of which have been published in the *Astronomical Journal.*

The computations on the Iris series in 1888 have been carried forward to an advanced stage, a large part of the work being done by Miss Margaretta Palmer. The heliometer observations have been reduced and compared with a provisional ephemeris and preliminary places of the comparison stars, the resulting equations of condition formed and a first solution of the same carried out. For the final solution a careful discussion of the errors of the ephemeris and the definitive places of the stars are required; these latter are to

be furnished by Prof. Auwers from the whole mass of meridian observations made in 1888 and 1889. The reduction of the polar triangulation is also nearly finished and requires only a final revision.

It is proposed during the ensuing season to devote the Heliometer to a series of measures on the satellites of Jupiter for the determination of their orbits and the mass of the planet, comparing them *inter se*, as has been done with such success by Herrmann Struve at Pulkova with those of Saturn. For this purpose it seems to me that in one important respect the heliometric method is not likely to be surpassed by other methods, and that is in the accuracy with which the scale-value and the orientation can be ascertained.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

Report for the year 1891–92, presented by the Board of Managers of the Observatory of Yale University to the President and Fellows.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.



## OFFICERS.

## In Memoriam.

### EDWARD MORDECAI REED.

The Board of Managers have lost by death their colleague, E. M. Reed, Esq., who died February 13, 1892. Mr. Reed was from his boyhood deeply interested in Astronomy, and in his later years he has aided the Yale University Observatory by his repeated gifts, and by his wise counsels. The Grubb Equatorial in the eastern tower was purchased and presented by him to the institution. By his will he has bequeathed to the Observatory the reversion of two-thirds of his estate to be used in carrying on our scientific work. The Board desires to place on record their high estimate of his generosity and personal worth.

# REPORT.

YALE UNIVERSITY, June 25, 1892.

*To the President and Fellows of Yale University:*

GENTLEMEN :—The Board of Managers herewith transmit the reports of Mr. Brown the Secretary of the Observatory, and of Dr. Elkin the Astronomer in charge of the Heliometer, The clocks and the time signals have been under the care of Mr. C. H. Ewing.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE OBSERVATORY, June 17, 1892.

*To the Board of Managers:*

GENTLEMEN :—I have the honor to report for the year ending with May 31, 1892, as follows:

### OBSERVATORY RESERVATION GROUNDS.

A few plantations of ornamental shrubs have been made, without cost to the Observatory; and a few trees have been planted.

### GROUNDS NORTH OF CANNER STREET.

The City Street Department has completed the grading of St. Ronan street, from Canner to Highland streets, so far as the "cuts" would go toward the "fills," making the street safe and passable, but leaving considerable filling to be made at each end of this section, before the established grade is attained. The fence posts have been set—and reset where the change of grade made this necessary—around the entire tract, except a small number at the east end of our Canner street frontage, where the sidewalk requires filling, which awaits action upon the proposed layout of the grounds, and location of roads, which will yield the material for this fill.

The contributions to the Library of the Observatory during the year ending with May 31st, 1892, have been as follows:

Becker Ludwig. On the Orbit of the Periodic Comet 1867 I. [Reprint from Mo. Not. R. A. S. Vol. LI, No. 8.] 8°. [*London*] 1891 — The Author.

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| The Academy. | Bologna. R. Accademia delle Scienze dell' Istituto. Memorie della Sezione delle Scienze Fisiche e Matematiche. Serie IV, Tomo X. 4°. *Bologna*, 1890. |
| —— | —— ——Del Meridiano Iniziale e dell' Ora Universale. [Estratto dal Rendiconto]. 8°. *Bologna*, 1890. |
| The Library. | Brunswick. Bowdoin College. Library Bulletin No. 1. 8°. *Brunswick*, 1891. |
| The Publishers. | Buffalo. Medical and Surgical Journal. June, 1891–May, 1892. 8°. *Buffalo*, 1891–92. |
| The Academy. | Bruxelles. L'Académie Royale des Sciences des Lettres et des Beaux Arts. Annuaire, 1890. 8°. *Bruxelles*, 1890. |
| —— | —— —— —— 1891. 8°. " *Bruxelles*, 1891. |
| —— | —— ——Bulletins. 59me Année, 3me Série, Tome XVII, 8°. *Bruxelles*, 1889. |
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| —— | —— —— ——60me Année, 3me Série, Tome XIX, 8°. *Bruxelles*, 1890. |
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| —— | —— —— ——61me Année, 3me Série, Tome XXI, 8°. *Bruxelles*, 1891 |
| The Observatory. | Cambridge. The Astronomical Observatory of Harvard College. Annals. 4°. Vol. XXVI, Part I. Preparation and Discussion of The Draper Catalogue. By Edward C. Pickering, Director. *Cambridge*, 1891. |
| —— | —— —— ——Vol. XXX, Part II. Observations at the Blue Hill Meteorological Observatory in 1890. *Cambridge*, 1891. |
| —— | —— ——Forty-sixth Annual Report of the Director. 8°. *Cambridge*, 1891. |
| —— | —— ——Time Service. 4°. *Cambridge*, 1891. |
| The Author. | Campbell, W. W. The Reduction of Spectroscopic Observations of Motions in the Line of Sight. [Reprint from Astronomy and Astro-Physics, No. 104.] |

Chapel Hill. Journal of the Elisha Mitchell Scientific Society. Vol. VIII, 1891. 8°. *Raleigh, N. C.*, 1891. — The Society.

Christiana. Supplement zu den Zonenbeobachtungen. H. Geelmuyden. 4°. *Christiana*, 1891. — The Observatory.

——Magnetische Beobachtungen und Stündliche Temperaturbeobachtungen im Terminjahre August 1882–August 1883 angestellt auf der Universitäts-Sternwarte. H. Geelmuyden 4°. *Christiana*, 1891. — ——

——Catalog der Astronomischen Gesellschaft. Erste Abtheilung. Catalog der Sterne bis zur neunten Grösse zwischen 80° Nördlicher und 2° Südlicher Declination für das Æquinoctium 1875. Drittes Stück, Zone + 65° bis + 70°. 4°. *Leipzig*, 1890. — ——

——Norwegisches Meteorologisches Institut. Jahrbuch für 1888. 4°. *Christiania*, 1890. — The Royal Norwegian Frederick Univ.

—— —— ——für 1889. 4°. *Christiana*, 1891.

W. H. M. Christie. On a New Dome to be erected at the Royal Observatory, Greenwich. [Reprint from Mo. Not. R. A. S. Vol. LI, No. 7.] 8°. *London*, 1891. — The Author.

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Córdoba. Anales de la Oficina Meteorologica Argentina por su Director, Gualterio G. Davis. 4°. Tomo VIII. Climas de Matanzas, Corientes, Catamarca, Mailin y Cochinoca. *Buenos Aires*, 1890 — J. D. and E. S. Dana.

——Resultados del Observatorio Nacional Argentino. Juan M. Thome, Director. 4°. Vol. XIII. Observaciones del año 1880. *Buenos Aires*, 1891. — ——

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| The Author. | W. Döllen. Stern-Ephemeriden auf das Jahr 1892. 8°. *Berlin*, 1891. |
| The Observatory. | Dorpat. Beobachtungen der Kaiserlichen Universitäts-Sternwarte, 18er Band. Reducirte Beobachtungen am Meridiankreise von Zonensternen und mittlere Oerter derselben für 1875.0. Dr. Ludwig Schwarz. 4°. *Dorpat*, 1891. |
| The Author. | N.-C. Dunér. Recherches sur la Rotation du Soleil. *Upsala*, 1891. |
| The Observatory. | Durban, Natal, S. Africa. Annual Report of the Superintendent, Natal Observatory, for the year 1890–91. E. Nevill, Government Astronomer. 4°. *Pietermaritzburg*, 1892. |
| —— | Edinburgh. Royal Observatory Circulars. Nos. 16–27. 8°. *Edinburgh*, 1891–92. |
| —— | Geneva. L'Observatoire de Genève. Résumé Météorologique de l'Année 1890 pour Genève et le Grand Saint Bernard. A. Kammermann. 8°. *Geneva*, 1891. |
| —— | —— ——Observations Météorologiques, Déc. 1889–Nov. 1890. *Geneva*, 1891. |
| —— | —— ——Rapport sur le Concours pour le réglage des Chronomètres pendant l'année 1891. Présenté à la Société des Arts, le 14 Mars 1892, par M. Raoul Gautier. 8°. *Geneva*, 1892. |
| —— | Georgetown. Georgetown College Observatory. The Photochonograph and its Application to Star Transits. 4°. *Washington*, 1891. |
| Astronomer Royal. | Greenwich. Royal Observatory. Rates of Chronometers on Trial for purchase by the Board of Admiralty. 4°. *London*, 1891. |
| —— | —— ——Rates of Deck Watches on Trial for purchase by the Board of Admiralty. 4°. *London*, 1891. |
| The Lords Commissioners of the Admiralty. | —— ——Assumed Mean Right Ascensions of Clock Stars with the corrections of the R. A. of the Nautical Almanac for 1892.0. 4°. *London*, 1801 |

Greenwich. Royal Observatory. Nautical Almanac and Astronomical Ephemeris for the year 1895. 8°. *London*, [1891.] — The Lords Commissioners of the Admiralty.

Havana. Observaciones Magnéticas y Meteorológicas del Real Colegio de Belen de la Compañia de Jesus. 4°. [To June 1889.] *Havana*, 1891. — The College.

Haverford College Observatory. Parallax of Lalande 1196=South 503. By F. P. Leavenworth. [*Haverford*, 1891.] — The Observatory.

—— ——Parallax of Delta Herculis. [From Haverford College Studies, No. 11.] (Includes Observations of Double Stars; of Comet Wolf (*b* 1891); and of Sun Spots.) 8°. [*Haverford*,] 1891.

Helsingfors. [Theses presented to the Royal Alexander University, Helsingfors.] Relander, H. M. J. Bestimmung der Minimalflächen welche eine Schaar reeler Curven zweiten Grades enthalten. 4°. *Helsingfors*, 1888. — The University Library, Upsala.

——Kerppola, K. Zur Theorie der biqvadratischen Reste. 4°. *Helsingfors*, 1888. — ——

——Brander, K. A. Beitrag zur Untersuchung elektrischer Erdströme. 4°. *Helsingfors*, 1888. — ——

——Genetz, Atle. Till teorin för de Fuchs'ka functionerna. 4°. *Helsingfors*, 1889. — ——

——Heinricius, P. A. Definitive Bahnelemente des Kometen 1887 III. 4°. *Helsingfors*, 1889. — ——

——Melander, G. De la Dilatation des Gaz à des Pressions inférieures à la Pression atmosphérique. 4°. *Helsingfors*, 1889. — ——

——Biese, Ernst. Das Verticalvariometer mit verticalen Magneten. 4°. *Helsingfors*, 1890. — ——

——Tallqvist, Hj. Bestimmung einiger Minimalflächen deren Begrenzung gegeben ist. 4°. *Helsingfors*, 1890. — ——

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By Dr. Elkin : "Astronomische Nachrichten ;" "The Astronomical Journal ;" "Vierteljahrsschrift der Astronomischen Gesellschaft ;" "Science."

By others : "Nature ;" "American Journal of Science and Arts."

The suggestion, in my last year's report, of a small Library Fund, has elicited no response.

### THERMOMETRIC BUREAU.

Mr. C. B. Peck has continued to make the thermometric comparisons, as heretofore.

As nearly all the clinical thermometers which come to the Observatory for certification require that their indices be first thrown down, this operation, performed by hand, on each singly, consumed much time, exhausted the observer when there were many at one time, and unfitted him for an immediately subsequent comparison, and was the occasion of the principal part of the breakage in our hands, when considerable force was required to reduce an especially refractory index. This led to experiments with, and the final putting in operation of a whirling table, which in a few seconds accomplishes safely what previously required many hours. The operation is also so safe and simple, that we now return the thermometers to the senders, with the indices thrown down, a thing we could not think of doing before.

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 8, 1892.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—The Heliometer has been in continuous use throughout the past year, and remains in good working order. The first accident of any consequence since it has been in my charge occurred last July, when the elastic pendulum rod snapped in two. It was, however, repaired in a day or two, and two duplicates ordered from Messrs. Repsold to guard against any delay which another similar mishap might cause. A small addition to the appliances has been in the shape of glass scales inserted in the Position (and Declination) microscopes. These scales subdivide the 10′ spaces on the circle directly into tenths of minutes and are convenient and time-saving when this accuracy is sufficient.

From July, 1891 to January, 1892 the satellites of Jupiter formed the principal object of work and we secured on 114 nights during that period 570 complete measures of their relative positions besides the necessary work on stars to keep a continuous control on the instrumental adjustments. The computations for such a series of intermutual positions will be quite extensive, but considerable progress has been already made on them, mainly by Miss Margaretta Palmer. The places of the satellites from the tables have all been deduced, and also all the differential coefficients for the equations of condition.

At this same opposition of Jupiter Dr. Gill has made a similar series with the Cape Heliometer and also a probably very valuable set of photographs of the satellites. We have undertaken the reduction of these series and a good part of the preliminary work has been accomplished, chiefly by Mr. John M. Moore.

Since the completion of this Jupiter work Dr. Chase has taken up again the measurement of the cluster in *Coma Berenices* and has brought that work to a close after securing from 18 to 20 measures for each of the 32 stars besides the requisite determinations for the reduction constants, and has kept the

computations for the adjustment and derivation of final results well in hand. He has also commenced a series of measures on Algol, at the suggestion of Dr. Chandler, to test the theory of a sensible orbital motion of the bright component of the system and the theoretical parallax derived therefrom. A series on the *nova* in *Auriga* was also begun in the hopes it would remain bright long enough to secure some knowledge as to its parallax, which hopes were, however, not realized as it sank rapidly out of sight with our instrument.

We have further made a series of measures on the well-known screw-value stars in *Perseus*, at the request of H. Struve, and have taken advantage of the present position of the earth's being nearly in the plane of Saturn's equator, to measure the polar and equatorial diameters of that planet.

For my own part, I have still continued to devote considerable time to the series on the parallaxes of the first magnitude stars in the Northern Hemisphere, and propose to keep up this work until I will have secured about 100 sets of measures of each of the ten stars. This number seems to be necessary to furnish values for the parallaxes with probable errors not much above 0".01, which accuracy it appears very desirable to obtain, in view of the exceptional character of and the interest attaching to these bright stars. It will require, probably, a couple of years more to accomplish this result, and it seems therefore worth while to state in brief the outcome of the work hitherto done with our Heliometer on these stars, remarking always, however, that this is not to be considered as our last word on the subject. The following table contains the mean results of the various series combined with regard to their probable systematic errors, and their probable errors as derived under the same assumptions.

| Star | Parallax | Prob. Error | No. of Comp. Stars | No. of Sets |
|---|---|---|---|---|
| α Tauri | + 0".101 | ± 0".022 | 6 | 65 |
| α Aurigae | + 0.095 | 0.021 | 5 | 51 |
| α Orionis | + 0.022 | 0.022 | 6 | 48 |
| α Canis minoris | + 0.341 | 0.020 | 6 | 48 |
| β Geminorum | + 0.057 | 0.021 | 6 | 48 |
| α Leonis | + 0.089 | 0.026 | 10 | 43 |
| α Bootis | + 0.016 | 0.018 | 10 | 89 |
| α Lyrae | + 0.092 | 0.019 | 6 | 67 |
| α Aquilae | + 0.214 | 0.023 | 10 | 46 |
| α Cygni | − 0.012 | 0.020 | 7 | 49 |

The values for $\alpha$ Tauri and $\alpha$ Bootis rest on the same observations as the ones communicated in my report in 1888, and differ from them only on account of a more correct system of combination of the several series. Of the eight remaining results, six are a close confirmation of the previous values, which were namely, for $\alpha$ Aurigae $+0''.107$, $\alpha$ Orionis $-0''.009$, $\beta$ Geminorum $+0''.068$, $\alpha$ Leonis $+0''.093$, $\alpha$ Aquilae $+0''.199$ and $\alpha$ Cygni $-0''.042$, all of which agree with the present results within the uncertainty they were considered subject to. The later series on Procyon and Vega give, however, considerably larger parallax values than the former ones, which were respectively $+0''.266$ and $+0''.034$, and it has been to a large extent this discordance and a certain discrepancy in the values for Aldebaran which have induced me to push the accuracy to the degree stated above.

This continuation of the work on the bright stars will, however, not completely fill my hands, and Dr. Chase's being also comparatively free it has been a matter of no little consideration, as to what direction our observing work with the heliometer could profitably take. It has seemed to me, finally, that it would be a promising task to undertake a reconnaissance survey, so to speak, of all the rapid moving stars within our reach, with a view to singling out those which are near enough to us to show a measurable parallax. A small number of observations with the Heliometer, say 3 or 4, at two successive maximum epochs of parallax would certainly show if this amounted to $0''.20$ for the star in question, and would probably give some indication if it were as great as $0''.10$. There are over 100 stars in the Northern Hemisphere with proper motions exceeding $0''.50$ per annum which have not been examined with adequate means in this regard, and according to our present knowledge of the absolute velocities of the stars there should be in such a number a few with small enough velocities to make their parallaxes fall in the category we could thus detect. But even should this not be the case, the purely negative result that there are probably no more stars in the Northern Hemisphere within a certain distance from us than those we already know of would have some considerable interest, and has seemed to warrant our putting our whole observational force into the plan—which will probably require two or three years to carry out.

We have still in hand the reductions of the series of measures made on Iris and the Polar triangulation in 1888. Certain systematic influences have come to light in their discussion and in Dr. Gill's comparison of the results of the Victoria triangulation which it seemed advisable to trace to their source. I think that this has been accomplished and that no further difficulties will present themselves to the satisfactory completion of these pieces of work.

Besides her work on the Jupiter series, Miss Palmer has carried out a determination of a definitive orbit for the Comet 1847, VI, discovered by Miss Maria Mitchell—her former teacher at Vassar College.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

Report for the year 1892–93, presented by the Board of Managers of the Observatory of Yale University to the President and Fellows.

# OBSERVATORY OF YALE UNIVERSITY.

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# REPORT.

YALE UNIVERSITY, June 26, 1893.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The Board of Managers herewith transmit the reports of Mr. Brown the Secretary of the Observatory, and of Dr. Elkin the Astronomer in charge of the Heliometer. The clocks and the time signals were under the care of Mr. C. H. Ewing until January, since which time they have been under the care of Dr. Chase.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE UNIVERSITY OBSERVATORY, June 17, 1893.

*To the Board of Managers:*

GENTLEMEN :—I have the honor to report for the year ending with May 31, 1893, as follows :

### GROUNDS NORTH OF CANNER STREET.

Pending the consideration, by your Board, of the recommendations heretofore made, little has been done here. Beyond the completion of the belt of shade trees—Elms— in the sidewalk about this tract, no expenditure has been incurred in the way of improvement; and in the way of maintenance, no more than was necessary to protect the woods from injury, by the timely and careful burning of the leaves and brush, and to prevent the stoppage of the drains and sewers by this material brought to their openings by the heavy rains.

Applications have been made for the purchase of building lots on the present street fronts, at prices formerly considered fair, and for some of the interior lots, if the proposed layout or something like it should be finally adopted. Nearly all the property on the Hillhouse ridge has been taken off the market, as far out as Canner street, and the recent increase in the facilities for access by the construction of the Winchester Street Railway and by the substitution of Electric motors, with more frequent trips, on the Whitney Avenue Street Railway, has advanced the value of all the property beyond.

The contributions to the Library of the Observatory during the year ending with May 31st, 1893, have been as follows :

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In addition to the foregoing, there have been placed upon the Library table, shortly after publication, as loans, the following periodicals :—

By Professor Newton : "The Observatory."

By Dr. Elkin : "Astronomische Nachrichten ;" "The Astronomical Journal ;" "Vierteljahrsschrift der Astronomischen Gesellschaft ;" "Monthly Notices of the Royal Astronomical Society," and "Science."

By others : "Nature ;" "American Journal of Science and Arts."

### THERMOMETRIC BUREAU.

Mr. C. B. Peck has continued to make the comparisons of thermometers, except during a short illness in the winter, when Mr. A. C. Alexander, Assistant in Physics in the Sheffield Scientific School, was kind enough to make such comparisons as could not wait for Mr. Peck's recovery.

It continues to be true that only a small percentage of the instruments sold are sent to us for certification. It is presumably true, also, that those which are sent here for certification, by the manufacturers, are carefully selected, and, therefore, far more reliable than the average of those sold without certification. Nevertheless we are sometimes compelled to reject 25, 50 and even 75 per cent. of those sent us. As a rule, these are not rejected without receiving double the care and time required by the large majority of those to which certificates are accorded.

When there is taken into account the large percentage which the cost of certification adds to the manufacturer's prices, it is not to be wondered at that when he has succeeded in continuously producing, for a season, instruments with few and uniform corrections, he should point to these conditions as justifying his customers in accepting his instruments without other certification than his own. In those cases of this sort which have come under our observation, we have noticed that apparently the workman, when he no longer has occasion to expect his work to be traversed by a disinterested authority, soon relaxes his efforts at an accuracy which is hardly yet fully appreciated by the ultimate consumer, and his instruments, when they come to us from his customers, are not quite up to the standard maintained when he was continuously, or at short

intervals, submitting them to such test: possibly he is not making due allowance for his changing standards.

It may not be out of place to again invite the attention of our public to some points in the construction of registering clinical thermometers, which are frequently overlooked by makers and users of these instruments.

In those forms where the index is a short column of mercury—one-third to one-half an inch long—separated from the rest of the mercury by a small bubble of air, the index is often lost by being thrown down into the bulb, the bubble escaping into the attenuated atmosphere of the tube, and when the index is restored the separating bubble is not likely to be of the same dimensions, and the temperature indications will not be the same as with the former bubble. The difference in the lengths of the tube occupied by the old and new bubbles will account, approximately for the differences in the readings. The bubble should always be as small as is consistent with its function of separating the columns of mercury. The tube should extend sufficiently beyond the maximum readings required, that the compressed atmosphere at the top of the tube may not force back the index, when the support of the mercury in the bulb is withdrawn by cooling.

In those forms where the "Indestructible index" is maintained by a "trap" near the bulb, the various constructions of this trap may, at certain points, cause the index to drop irregularly when the mercury below the trap has contracted, or may occasion a motion of the index by jumps: in fact in most of the reliable instruments of this form, it is merely a question of the number of jumps taken by the index in rising one degree;—most of those in which the index rises perfectly smoothly and without jumps, will justify the suspicion that the index will drop, as soon as the mercury in the bulb contracts from the trap. While the index is rising freely the motion may appear continuous, but when the index is within a degree or two of coming to rest and rising slowly, the jumps may, usually, easily be counted. Our recent practice has been that, when these jumps average $0^\circ.1$ or less, and the readings repeat themselves, throughout, within the prescribed limit of accuracy, the usual certificate is given: if the jumps average more than $0^\circ.1$ and less than $\frac{1}{8}^\circ$,—the readings repeating themselves as before, we modify the certificate by making

the limit of accuracy "$0^\circ.2$" on the same certificate form : and when the jumps average more than $\frac{1}{8}^\circ$, we give no certificate. The process of producing the trap leaves its walls in a somewhat unstable condition, so that moderate concussions may cause particles of glass to separate, which particles, acting as a plug, may temporarily sustain the index, which, when the plug is dislodged may drop. The contraction here is so small, and the particles of glass so fine, that it is not always easy to detect them. The same dropping of the index may be due to the varying effect of air in the trap. For the more certain and rapid counting of the jumps in this class of instruments Mr. Peck has recently contrived an ingenious apparatus which he has now in practical use.

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 26, 1893.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—The work with the Heliometer has been carried forward during the past year in the directions outlined in my last report.

We have examined so far, 51 stars of large proper motion making in general three sets of measures at each parallax maximum. We have not, however, been able to keep the reductions quite up to date, so that I cannot, at this moment, give any definite results of our search for large parallaxes.

I have also continued the series of parallax measures on the first magnitude stars—Aldebaran, Procyon, Regulus, Arcturus and Vega having been followed up this year.

Dr. Chase has continued the work on Algol, and has commenced a series on *β Cygni* to test the large parallax deduced by Mr. Jacoby from the Rutherfurd photographic plates. He has also been engaged upon, and nearly completed the reduction of his measurements in *Coma Berenices.*

Miss Palmer has been mainly occupied with the computations of our series on Jupiter's Satellites, a work of considerable extent.

At the request of Prof. Van Vleck of Wesleyan University, Middletown, we have made time observations and exchanged signals on 2 nights, for the determination of their longitude.

Parts III and IV of our Transactions, containing the Polar triangulation and Miss Palmer's orbit of Comet 1847 VI, have been printed and distributed.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1893–94, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

Rev. TIMOTHY DWIGHT, D.D., LL.D., *President.*
Professor HUBERT A. NEWTON, LL D., *Secretary.*
WILLIAM W. FARNAM, M.A.
THOMAS G. BENNETT, PH.B.
Professor CHARLES S. HASTINGS, PH.D.

## OFFICERS.

ROBERT BROWN, M.A., *Secretary.*
WILLIAM L. ELKIN, PH.D., *Astronomer in charge of the Heliometer.*
FREDERICK L. CHASE, PH.D.. *Assistant.*

# REPORT.

YALE UNIVERSITY, June 23, 1894.

*To the President and Fellows of Yale University:*

GENTLEMEN :—The Board of Managers herewith transmit the reports of Mr. Brown the Secretary of the Observatory, and of Dr. Elkin the Astronomer in charge of the Heliometer.

Dr. Elkin's success in securing meteor tracks by photography in August and December led the Board to make application to the National Academy of Sciences for an appropriation from the income of the J. Lawrence Smith Fund to aid in making photographic records of meteor tracks. The Academy has given us an appropriation of two thousand dollars for this purpose. An equatorial axis designed to carry photographic cameras and to be controlled by a suitable clock-movement has therefore been ordered and is being constructed by Messrs. Warner & Swasey, of Cleveland, Ohio.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE UNIVERSITY OBSERVATORY, June 19, 1894.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report for the year ending with May 31, 1894, as follows:

### THE OBSERVATORY GROUNDS.

No expense has been incurred for the improvement of the lot in which the Observatory stands. Dr. Elkin has contributed three large Norway Spruce trees, with the expense of transplanting them to the north-west corner of the grounds. A row of ten maple trees, of three species, was planted on Arbor Day, 1894, along the south-east line of the south-west drive, as far as room was allowed by the evergreens on our south border.

### GROUNDS NORTH OF CANNER STREET.

The fifteen-inch drain was extended ninety-two feet to the north-west, under the low ground, and the pipe is on hand for a further extension of one hundred and seventy feet, when it can most economically be done.

### THE LIBRARY.

A number of unbound Star Catalogues, which are in continuous use are rapidly going to pieces, and it is very desirable that a few of the most valuable and indispensable of these should be strongly bound; for which use no funds are at my command. In response to a suggestion in the Report for 1891, a conditional subscription of $500.00 has been made, payable when a total sum of $5,000,00 shall have been subscribed for a fund, the income of which shall be applied to the purchase of books.

The contributions to the Library of the Observatory during the year ending with May 31, 1894, have been as follows:

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* In the Report for the year 1892–93, p. 6, l. 11, for *1870* read *1890*.

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| ——Data, for Computing the Positions of the Satellites of Jupiter 1893–94. [Ibid. No. 9.] *London*, 1893. | —— |
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By Professor Newton: "The Observatory."

By Dr. Elkin: "Astronomische Nachrichten;" "The Astronomical Journal;" "Vierteljahrsschrift der Astronomischen Gesellschaft:" "Monthly Notices of the Royal Astronomical Society," and "Science."

By others: "Nature;" "American Journal of Science and Arts."

THE THERMOMETRIC BUREAU.

Mr. Peck has continued to make the comparisons of thermometers. The general stagnation in the business affairs of the country has naturally checked the increase in the numbers of instruments sent here for verification. The number of instruments rejected by us has been rather less than heretofore, ranging from 10 to 20 per cent.—the defective ones being, apparently, more carefully culled by the makers or senders.

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 14, 1894

*To the Board of Managers of the Observatory:*

GENTLEMEN:—The Heliometer has been utilized since my last report in carrying on the two pieces of work we have been engaged on in the last few years. I have made new series for the parallaxes of Capella, Procyon and Altair, bringing the whole number of series I have secured for the ten first magnitude stars to 54. Dr. Chase has obtained measures of 24 large proper motion stars, making 75 in all of these stars we have examined for the purpose of detecting any parallax as large as $0''.20$. Dr. Chase has also completed series on Algol and *β Cygni* the results of which have been communicated to the *Astronomical Journal.* Owing to his having taken up the instruction in Astronomy in the Sheffield Scientific School, he has not been able to quite complete the reductions of the *Coma Berenices* triangulation as yet.

Miss Palmer has been engaged in the computations relative to the series of measures of Jupiter's Satellites. The normal equations resulting from the 1,128 equations of condition, each with 13 unknown quantities, have been formed, but not yet solved.

I have gone over the work on *Iris* made with the Heliometers at the Cape, Leipzig, Oxford and here for the determination of the Solar Parallax applying the systematic corrections for each observer as far as they have been deduced or could be estimated. While I do not feel certain that I have arrived at the best solution in view of the difficulties presented by these systematic errors and the unavoidable irregularities of the ephemeris computed with 7-figure logarithms, yet as far as I can judge the final result is not greatly affected by these sources of error. The value for the solar parallax which seems to me most plausible at present, I have derived by using only practically simultaneous observations, thus eliminating the ephemeris errors, and by allowing reduced weights to the smaller distance measures, which are the most affected by the personal errors. This value is

**$8''.825$ with the probable error $0''.008$,**

and this probable error allows to the best of my belief for all sources of systematic error excepting those due to a possible difference of refraction of the planet and the comparison stars, and to the uncertainty of our data concerning the figure of the earth.

A considerable part of my time has been spent in experiments with reference to the photography of meteors. A six-inch Voigtländer portrait lens, presented to the Observatory by Cyprian S. Brainerd, Esq. (Y. C. 1850), was mounted on the stand of our Reed equatorial and a small glass loaned by Prof. Newton used as a guiding telescope. An area of about 200 square degrees was exposed to points near the radiant of the Perseids on August 9 and 10 last, and during an exposure of eight hours on these nights, two hours of which, however, were almost nullified by cloud and haze, three meteor trails were photographed; two of which were true Perseids. A visual watch on the region covered by the plate was kept by Mr. Brown, Dr. Chase and myself for the safe identification of the meteor tracks.

On December 10 and 11 last, a second similar lens was also in use, and during six hours exposure of the two fields, three trails of Geminids were impressed on the plates. These results seem to justify the conclusion that with a still larger field a sufficient number of tracks would be secured to afford reliable data for the radiant, and on the application of the Board of Managers, the National Academy has voted a grant of two thousand dollars for the purpose of allowing us to construct a mounting which would carry a number of cameras. This is now under construction by Messrs. Warner and Swasey, and we hope that it will be finished in time for the August meteors of this year.

I have carried out a rigid computation of the results derivable from the Perseid tracks, including a track of one of them secured by Mr. Lewis of Ansonia. The radiant resulting from our two tracks freed from the effects of zenithal attraction and diurnal aberration is

$$\alpha = 46^\circ\ 39'.1 \quad \delta = +58^\circ\ 0'.1 \text{ for } 1875.0$$

For the Geminid trails Prof. Newton has made a provisional computation, using the rough star places of the Durchmusterung, and finds that the three trails when corrected for zenithal

attraction and prolonged backwards are tangent to a circle of less than 1′ diameter. I have delayed carrying out a definitive solution until I could secure the modern star places of the Berlin Zone which have been kindly promised us by Prof. Foerster.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1894–95, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY

## BOARD OF MANAGERS.

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ROBERT BROWN, M.A., *Secretary*
WILLIAM L. ELKIN, PH.D., *Astronomer in charge of the Heliometer.*
FREDERICK L. CHASE, PH.D., *Assistant.*

# REPORT.

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YALE UNIVERSITY, June 22, 1895.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The Board of Managers herewith transmit the reports of Mr. Brown, the Secretary of the Observatory, and of Dr. Elkin, the Astronomer in charge of the Heliometer.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE UNIVERSITY OBSERVATORY,
NEW HAVEN, CONN., June 21, 1895.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report for the year ending with May 31, 1894, as follows:

### THE OBSERVATORY BUILDING.

The wood-work of this building—principally the Transit Room and the frame room serving as an approach to the East Tower—not having been painted since 1882, has this Spring been given a good coat of paint, with the intention of soon giving it a second coat, as little was left of the original paint. Some sort of vestibule is needed for the entrance to the building. The present door is a very light one, probably intended for an interior door. It has shrunken and the sill has worn away so that much water is driven in during an easterly rain storm, and wind during cold weather, so that with waste of fuel, the building is at times too cold for sedentary work. With a light portable vestibule covering the top of the present platform, in winter, the present door could be mended to suffice perhaps better than by replacing the door—a double one—by a heavier.

### THE OBSERVATORY GROUNDS.

A cemented 4-inch Akron tile drain has been laid from the roof-water-conductor in the middle of the north side of the main building, to connect with the sewer drain west of the West Tower. This new drain has been laid at such depth that it can be extended with a sufficient incline to receive the water from the north side of the proposed extension between the present main building and the East Tower, whenever that shall be made, or from the present East Tower whenever that may seem desirable. The water-conductors from the north side of the Transit Room have also been connected with the drain. At the same time, on account of an obstruction in the plumbing which caused continued or repeated overflows from the sinks in the Thermometer Testing Room, a connection was made with this drain through the north wall of the cellar

beneath, and through a hydraulic trap on the outside of the building, and in such a manner that inspection can readily be made and any future obstruction located and removed, without severing any pipes.

Heretofore the rain-water from the roof of the Transit Room has run under the room and *may* prove, when a similar connection on the south side has been provided for the prompt removal of the other half of the water, to have been the cause —or the partial cause—of a slight variation in the Transit piers, not otherwise accounted for.

The water heretofore shed from the roof of the main building has repeatedly washed out the sod and cut up the driveway, so that this betterment will be justified by the reduction of expense upon, and improved condition of, the driveway and the turf.

On the north side of the north driveway and west of the center line through the building, a small amount of regrading has been done.

Mention was omitted in the last Annual Report that in November, 1893, the boundary line between the Observatory Reservation and the land on the east and south, belonging to the estate of Massena Clark, deceased, was re-surveyed with this result: the point in the north line of the Winchester estate where the dividing line takes its origin was found substantially correct, but at the north end this line was found to be about seven feet east of the old fence: and the line thence to St. Ronan st. was found to be about two feet south of the old fence—substantially agreeing with my former rough measures. On this re-surveyed line Mr. Clarke's estate erected a temporary, but at present sufficient fence, the respective parties in interest paying each his proportional share of the cost.

### ST. RONAN ST. LOT.

Tall cedar fence posts have been set on the east line of the lot on St. Ronan st., south from Canner st., with wire fencing, which can be moved up on the posts as the street and sidewalk are filled.

### GROUNDS NORTH OF CANNER STREET.

The further extension of the 15-inch drain awaits instructions as to lines and grades.

The contributions to the Library of the Observatory during the year ending with May 31, 1895, have been as follows:

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In addition to the foregoing there have been placed upon the Library table, shortly after publication, as loans, the following periodicals:—

By Dr. Elkin: "Astronomische Nachrichten;" "The Astronomical Journal;" "Vierteljahrsschrift der Astronomischen Gesellschaft:" "Monthly Notices of the Royal Astronomical Society," and "Science."

By another: "American Journal of Science and Arts."

## THE THERMOMETRIC BUREAU.

The closing remarks of the last Annual Report may be repeated.

"Mr. Peck has continued to make the comparisons of thermometers. The general stagnation in the business affairs of the country has naturally checked the increase in the numbers of instruments sent here for verification. The number of instruments rejected by us has been rather less than heretofore, ranging from 10 to 20 per cent.—the defective ones being, apparently, more carefully culled by the makers or senders."

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 15, 1895.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—In the past year the work with the Heliometer has been carried forward on the lines indicated in my past reports. I have continued and brought to what I hope is a final close the series on the parallaxes of the first magnitude stars and hope to present the definitive results in the near future. The series on the parallaxes of the large proper motion stars, on which Dr. Chase has been mainly engaged, now comprises 99 stars, all but two of which have been observed at two parallax maximum epochs, in general on three nights. It seems desirable, however, before drawing any conclusions from these data, to eliminate the effect of the proper motion, and we therefore propose to secure two further epochs for each star. In pursuance of this plan, nine stars have already been taken at a third epoch. We attempted measures of the Moon's diameter at the total eclipse of March 25, last, and measures of Mercury referred to the Sun's limb at the transit on Nov. 10, last, but in both cases the state of the sky permitted our obtaining only a small amount of results. The last contacts of the transit were, however, secured by Mr. Brown and Dr. Chase.

An agreement has been made with Dr. Gill that the observations and discussion of the *Iris* series for the determination of the solar parallax should be printed and included with his similar investigations on *Victoria* and *Sappho*, and the papers have been forwarded to him. In revising the work for final publication I have found that the distances of the planet from the Sun used probably require a small correction and that an observation was included which did not refer to the planet. The effect of the requisite emendations is to slightly reduce the value of the solar parallax given in my last report as the result of the *Iris* series.

The reductions of the *Coma Berenices* triangulation have been completed practically, and the work will shortly be ready for the press. I regret to say that, owing to a long and serious

illness of Dr. Palmer, considerable work yet remains to be done on the Jupiter satellite series.

The equatorial mounting constructed for us by Warner and Swasey for carrying a number of cameras, reached us at the end of July last, and was set up in time to be used on three nights of the August meteor period, August 9, 10 and 11. It carried four cameras, two with lenses of about 6 inches, and two with such of about 5 inches effective aperture, and these four fields were exposed in all about 11 hours. I must confess to some considerable disappointment in finding only two meteor trails on our plates as a result of this first trial of our new apparatus, but I hope with added experience and care to be more fortunate this coming season. We also made exposures on the dates of the November and December showers, but with only negative results, owing possibly partly to the unfavorable position of the moon.

It seems to me, however, that as other observers begin to take up such work, we will eventually be able to reach some valuable results from the photographic data as they accumulate. Already we are in possession of some twelve impressions of Perseid trails, four of which were secured here and two at Ansonia by Mr. John E. Lewis working in collaboration with us. Prof. Barnard has furthermore kindly sent us three plates exposed also on Aug. 9, 10 and 11, 1894, for about 8 hours in all, which show four and possibly five meteor trails. And finally Prof. Pickering has found on an examination of the Harvard Observatory plates one fine trail on a plate taken Aug. 8, 1893, and kindly sent it to us for measurement. I have carried out a discussion of these trails, which will be very shortly ready for publication and seems to lead to some interesting conclusions.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

REPORT FOR THE YEAR 1895–96, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

Rev. TIMOTHY DWIGHT, D.D., LL.D., *President.*
Professor HUBERT A. NEWTON, LL.D., *Secretary.*
WILLIAM W. FARNAM, M.A.
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Professor CHARLES S. HASTINGS, PH.D.

## OFFICERS.

ROBERT BROWN, M.A., *Secretary.*
* WILLIAM L. ELKIN, PH.D., *Astronomer in charge of the Heliometer.*
FREDERICK L. CHASE, PH.D., *Assistant Astronomer.*

* While this Report is in the hands of the printers, Dr. Elkin has, in his absence, been made Director of the Observatory.

# REPORT.

YALE UNIVERSITY, June 22, 1896.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The Board of Managers herewith transmit the reports of Mr. Brown, the Secretary of the Observatory, and of Dr. Elkin, the Astronomer in charge of the Heliometer. The clocks and the time signals have been under the care of Dr. Chase.

Respectfully submitted by

THE BOARD OF MANAGERS.

## SECRETARY'S REPORT.

YALE UNIVERSITY OBSERVATORY,
NEW HAVEN, CONN., June 17, 1896.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report for the year ending with May 31, 1896, as follows:

### THE OBSERVATORY BUILDING.

The re-painting of the outside of the building, in progress at the time of my last report, has been continued, at intervals. The furnace was patched and made to last through the winter; probably parts of the furnace will require to be replaced before the coming winter.

A dark closet for photographic uses was constructed by partitioning off the west side of the north-east chamber on the second floor, by means of Neponset building paper on light scantlings; light from gas burners in the adjacent room being admitted through appropriately colored windows, and the north window being darkened.

### THE OBSERVATORY GROUNDS.

The water conductors on the south side of the Transit Room were connected with the sewer drain on this side of the building, in like manner as reported last year concerning the north side. The bottom of this connecting drain is, at the line of the building, 49 inches below ground, and is planned to drain off any water that may accumulate at that depth about the piers of the transit instrument. The plans of these drains will be found on pages 43 and 44 of Letter Book, No 4.

A few trees injured by boring insects were replaced, and a few small trees added to the grounds—including a horse chestnut and an ash-leaved Negundo, west of the north-east drive. On the north-east side of the north-west drive a little regrading was done.

### GROUND NORTH OF CANNER STREET.

An elm tree on St. Ronan Street next north of Canner Street was replaced, as also one on the north side of Canner Street near the top of the hill. The City authorities have at length required sidewalks to be laid this summer, from St. Ronan Street, eastward, which will make the lots on St. Ronan Street more accessible and more marketable. This is certain at no distant day to become a beautiful street.

The contributions to the Library of the Observatory during the year ending with May 31st, 1896, have been as follows :

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| Bonn. Königliche Sternwarte. Veröffentlichungen. No. I. Beobachtungen von Nebelflecken, von Dr. C. Mönnichmeyer. 4°. *Bonn*, 1895. | The Observatory. |
| Boston. American Academy of Arts and Sciences. Proceedings. New Series. Vol. XXII. 8°. *Boston*, 1895. | The Academy. |
| —— Public Library. Forty-third Annual Report. For 1894. *Boston*, 1895. | The Library. |
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| —— —— —— $65^{me}$ Année, 3me Série, Tome XXIX. 8°. *Bruxelles*, 1895. | —— |
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| Buffalo. Medical and Surgical Journal. June, 1895–May, 1896. 8°. *Buffalo*, 1895–96. | The Publishers. |
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| The Observatory. | ——— ——— ——— Vol. XL, Part IV. Observations made at the Blue Hill Meteorological Observatory in the year 1894. Under the direction of A. Lawrence Rotch, A. M. *Cambridge*, 1895. |
| ——— | ——— ——— ——— Vol. XLI, No. III. Observations of the New England Weather Service in the year 1894. By J. Warren Smith. *Cambridge*, 1895. |
| ——— | ——— ——— Fiftieth Annual Report of the Director. 8°. *Cambridge*, 1895. |
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By Dr. Elkin : " Astronomische Nachrichten ;" " The Astronomical Journal ;" " Vierteljahrsschrift der Astronomischen Gesellschaft ;" " Monthly Notices of the Royal Astronomical Society," and " Science."

By others : "American Journal of Science and Arts" and " Knowledge."

### THE THERMOMETRIC BUREAU.

The number of thermometers received for verification, and proportion rejected remain about the same. Mr. Peck, besides making these comparisons, as heretofore, has given considerable time to the consideration of the most feasible and most accurate methods of determining temperatures between 100° and 300° C., for which there is some demand, and where the limit of accuracy is larger than we are satisfied to have it remain.

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

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## REPORT OF DR. ELKIN.

YALE UNIVERSITY, May 1, 1896.

*To the Board of Managers of the Observatory :*

GENTLEMEN :—The series of measures for the purpose of detecting possible large parallaxes of stars with large proper motion has been carried on during the past year by Dr. Chase and myself. A few stars have been added to the list to fill up the gaps which presented themselves in the course of observing. As at present planned, the work will be completed probably in the course of 1897, as far as the observations are concerned.

The series on the parallaxes of the first magnitude stars is, as stated in my last report, practically brought to a close, and only a few points of discussion remain to be revised.

A considerable portion of my time has been devoted to a final revision of the discussion of the work on Iris as it passed through the press. This has now been accomplished, and the work will shortly appear as Part IV of the work issued by Dr. Gill on the determination of the Solar Parallax by Heliometer measures of Asteroids.

Dr. Chase has passed through the press his work on the relative places of the principal stars in the cluster in Coma Berenices, and it is ready for issue as Part V of our Transactions.

I regret to say that we were not successful in the past season in securing photographic records of meteor trails. The apparatus was put in use during several nights of the August showers, but no meteors appeared of sufficient brilliancy to impress themselves on the plates, which had necessarily become somewhat fogged by the strong moonlight. We were equally unfortunate in our attempts on the Leonids and Geminids in November and December, respectively. During this year we have had only two lenses in use, as no further ones of sufficient size and quality were to be found in the market. It seems wise, however, in view of the favorable chances for the Perseids this year, and the approaching maximum of the Leonids, to make an especial effort to secure a complete battery for our mounting as originally planned.

Respectfully,

W. L. ELKIN,

*Astronomer in charge of the Heliometer.*

From Yale University Observatory
Dec. 6. 1897

Report for the year 1896–97, presented by the Board of Managers of the Observatory of Yale University to the President and Fellows.

# Observatory of Yale University.

## BOARD OF MANAGERS.

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Frederick L. Chase, Ph.D., *Assistant Astronomer.*

# REPORT.

YALE UNIVERSITY, June 26, 1897.

*To the President and Fellows of Yale University :*

GENTLEMEN :—The Board of Managers herewith transmit the Reports of Dr. Elkin, who was appointed Director of the Observatory at the meeting of the Corporation in June, 1896, and of Mr. Brown, Secretary of the Observatory.

Since the date of our last report we have lost by the death of Professor Hubert A. Newton one of our earliest as well as one of our most efficient members. Professor Newton had, from the very first inception of the plan which resulted in the establishment of the Observatory, felt the deepest interest in it and manifested his interest by his constant thoughtfulness and effort in its behalf. From 1882 to 1884 he held the office of Director, and after resigning the position he continued to discharge a large part of the duties connected with it. This he did without compensation, and he furthermore aided generously in the effort to maintain the Observatory in the first years of its existence. For these invaluable services the Board of Managers wish to express their sense of deepest recognition.

Respectfully submitted by

THE BOARD OF MANAGERS.

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 23, 1897.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—I returned from abroad early in July last in time to prepare for photographing the August meteors.

While in Europe I purchased a third Voigtländer lens and one by Hermagis, both of six inches aperture, and since my return have procured two other similar ones of American make, thus making six cameras available on our mounting. The cost of all three of our Voigtländer lenses has been generously defrayed by Cyprian S. Brainerd, Esq. Five lenses were put in use in August last and eight meteor trails, five of them Perseids, were secured. The November and December periods were, however, unproductive this year.

A considerable part of my time has been employed in the measurement and discussion of the photographic trails of the Perseids thus secured, now numbering 17 in all. So far, the results are not very conclusive as to the character of the radiant, but as each year, we trust, will add to our data, there seems good reason to hope ultimately for most valuable deductions. Mr. John E. Lewis has rendered valuable coöperation in this work, though he did not secure any trails at Ansonia.

I regret to have to say that owing to a severe attack of influenza I have otherwise been obliged to curtail my observing work during most of the year, devoting myself to arrears of discussion and reduction, and have had to be absent from New Haven in the spring months in a more Southern climate.

During the winter, however, a portion of the work on the parallaxes of the ten first magnitude stars in the Northern Hemisphere, comprising the observations and reductions, has been passed through the press. In anticipation of the complete publication of the work I may say that, without entering into further details, the following are values which can hardly be modified appreciably by further discussion:

| Star. | Parallax. | Prob. Error. | No. of Series. | No. of Stars. | No. of Obs. |
|---|---|---|---|---|---|
| α Tauri | +0″.107 | ±0″.013 | 9 | 18 | 171 |
| α Aurigae | +0.081 | 0.016 | 4 | 7 | 57 |
| α Orionis | +0.023 | 0.017 | 3 | 6 | 48 |
| α Canis minoris | +0.325 | 0.018 | 7 | 13 | 128 |
| β Geminorum | +0.056 | 0.016 | 3 | 6 | 48 |
| α Leonis | +0.022 | 0.022 | 5 | 12 | 74 |
| α Bootis | +0.024 | 0.015 | 7 | 13 | 126 |
| α Lyrae | +0.082 | 0.014 | 7 | 14 | 143 |
| α Aquilae | +0.231 | 0.019 | 5 | 14 | 79 |
| α Cygni | −0.012 | 0.015 | 3 | 7 | 49 |

Dr. Chase was absent in Europe on leave from July, 1896, to January, 1897. Since his return he has taken up the Heliometer work on the parallaxes of large proper motion stars and prosecuted it with great devotion and energy—in addition to carrying on the time service and teaching one term in the Scientific School. During his absence the time service was under the care of Mr. George K. Lawton until October, 1896, and subsequently under that of Dr. B. W. McFarland.

Dr. Palmer has been engaged in computations, mainly of refraction corrections and tables therefor. Miss Newton has been occupied in preparing a series of references to other catalogues in an interleaved copy of the Bonn Durchmusterung.

Respectfully,

W. L. ELKIN.

## SECRETARY'S REPORT.

YALE UNIVERSITY OBSERVATORY,
NEW HAVEN, CONN., June 25, 1897.

*To the Board of Managers:*

GENTLEMEN:—I have the honor to report for the year ending with May 31, 1897, as follows:

### THE OBSERVATORY BUILDING.

In the construction of the present half of the Observatory building (as planned), the east wall was regarded as a partition from the main halls (upper and lower), and not intended for many years' exposure to the weather. While this wall shows, as yet, no serious inroad of the storms, the light door which has served as the entrance to the building, has offered, each year, less and less resistance to the wind and rain, until it became necessary last winter to add the protection of a winter vestibule.

The stairs to the East Tower were repaired and painted.

The West Tower was painted an olive green on the inside.

The inside of the high fence about the Photographic Observatory was painted red, on account of the reflection of light into the cameras from the white paint first employed.

The outside blinds of the building were repainted. All the painting mentioned in this and in late reports has been done by Mr. Toohey, the acting janitor of the building.

The growth of the library will make it necessary to add a number of book cases during the coming year.

### THE OBSERVATORY GROUNDS.

A few ornamental shrubs have been added, at the cost of planting. The large chestnut trees were pruned of a number of dead branches which marred their appearance and drew upon their vitality. One elm tree has been planted on the west side of St. Ronan street, next north of our south line.

The wooden coverings over the street gutters at the Prospect street entrances to the Observatory and to the dwellings having completely decayed, six-inch iron pipes were substituted, one and two years ago, and have proved to be more easily cleaned and kept clean, and will call for no further repair.

None of the elms, either within the Observatory grounds, or upon the north lots, or on any of the adjacent sidewalks, were seriously injured by the "Elm-tree Beetle" (*Galerucella luteola*), which caused so much damage in this city and elsewhere during last year and the preceding one. Unable to pay for the spraying with the kerosene emulsion of the large number of trees under our care, we were forced to be content with the method of trapping the larvæ in folds of muslin tied about the trees, where they transformed into pupæ, and were gathered and destroyed every week, the pupa period being ten days. They have now pretty much disappeared through the combined efforts of insect, bird and man.

The contributions to the Library of the Observatory during the year ending with May 31st, 1897, have been as follows:

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| —— —— —— VIII. Band. Breiten–Azimut–und Winkelbestimmungen. 4°. *Vienna*, 1896. | —— |
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By Dr. Elkin: "Astronomische Nachrichten;" "The Astronomical Journal;" "Vierteljahrsschrift der Astronomischen Gesellschaft;" "Monthly Notices of the Royal Astronomical Society," "Science" and "Nature."

Also: "American Journal of Science and Arts."

THE THERMOMETRIC BUREAU.

The number of thermometers received for verification, and proportion rejected, remain about the same as last year. Mr. Peck has continued in charge of this department.

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

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REPORT FOR THE YEAR 1897–98, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# OBSERVATORY OF YALE UNIVERSITY.

## BOARD OF MANAGERS.

Rev. TIMOTHY DWIGHT, D.D., LL.D., *President.*
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WILLIAM L. ELKIN, PH.D., *Director.*
ROBERT BROWN, M.A., *Secretary.*
FREDERICK L. CHASE, PH.D., *Assistant Astronomer.*

# REPORT.

YALE UNIVERSITY, June 26, 1899.

*To the President and Fellows of Yale University :*

GENTLEMEN —The Board of Managers herewith transmit the Reports of Dr. Elkin, Director, and of Mr. Brown, Secretary of the Observatory.

We have to acknowledge a grant of one thousand dollars from the J. Lawrence Smith Fund of the National Academy of Sciences, for which we beg to render our thanks.

Respectfully submitted by

THE BOARD OF MANAGERS.

## REPORT OF DR. ELKIN.

YALE UNIVERSITY, June 12, 1899.

*To the Board of Managers of the Observatory:*

GENTLEMEN:—The heliometer has been employed during the past year in securing the final measures for the parallax series on stars of large proper motion, which has thus been brought to a close. The reduction of the results are also approaching completion and will probably be available in the near future. Dr. Chase has also continued the investigation on the refraction of highly colored red stars in order to strengthen the results already obtained. These appear to show that systematic error from this source is hardly to be feared with the heliometer, and hence further discussion of our parallax results to be scarcely requisite.

With the aid of the grant from the J. Lawrence Smith fund of the National Academy, a second station for photographic observation of meteors was put up in Hamden, about two miles in a northerly direction from the Observatory, on the grounds of the late O. F. Treadwell, Esq. (Yale Coll. 1862). The apparatus used was a simple form of equatorial mounting without clockwork, and carried four cameras with portrait lenses of about five inches aperture. Dr. Chase took charge of this station, and it was first put into operation at the August meteor period of last year. Owing to moonlight and the generally hazy and damp atmosphere, only one meteor trail was secured, which was, however, not a Perseid, while at the Observatory station only this meteor and one other, a Perseid, were recorded.

At the epoch of the Leonid shower, which is now near its maximum, watch was kept throughout the nights of Nov. 12 to 16, and complete records obtained on the two nights, Nov. 14 and 15. On these in all 16 meteor trails were impressed on the plates at the two stations, 10 at the Observatory, and 6 at Hamden, 8 of which were Leonids. Four meteors were recorded at both stations, but unfortunately only one of these

was a Leonid. The results of the discussion of the Leonid trails (published in the Astrophysical Journal) show the close accordance and consequent high value of the photographic records. An interesting by-product of the work was the discovery, on examining the plates on Nov. 21, of a faint comet by Dr. Chase, who subsequently followed it with the Grubb equatorial until Dec. 15.

The Geminid shower was quite pronounced on Dec. 11, and two meteors from this radiant were secured at both stations, besides a fifth trail at the Observatory. Two other sporadic meteors were also recorded at both stations at this epoch, but the Orionid, Andromedid, Quadrantid and Lyrid showers were unproductive this year, though carefully watched for. In this photographic work Mr. M. F. Smith has rendered efficient service as well as in the subsequent reductions and computations relating to the same.

The time service has been under the charge of Dr. Chase excepting a portion of last year, when it was carried on by Mr. Smith. During a part of the year Dr. Palmer and Miss Newton have been engaged in computing for the Observatory.

Respectfully,

W. L. ELKIN.

## SECRETARY'S REPORT.

YALE UNIVERSITY OBSERVATORY,
NEW HAVEN, CONN., June 17, 1899.

*To the Board of Managers of the Yale Observatory :*

GENTLEMEN :—I have the honor to report for the year ending with May 31, 1899, as follows :

### THE OBSERVATORY BUILDINGS.

The iron clamps holding together the pieced chimney caps were found almost rusted away, and were replaced with more substantial ones, and these bedded in cement. The chimneys and the east gable were pointed up with cement where the original mortar was reduced to little better than sand. The tin roof was repaired on the northeast corner where it had been loosened and partly torn away by high winds. Such painting was done as seemed neeessary to preserve the woodwork and the tin roof from the effects of the weather. The library shelving has been further postponed, at the expense of increased crowding and disarrangement. The water supply, while improved, cannot yet be depended upon at the hours of the day when it is most necessary for photographic purposes.

### THE LIBRARY.

Among the more valuable additions to the Library should be mentioned the approximate completion of our set of the "Memoirs" and "Monthly Notices" of the Royal Astronomical Society, mainly by the gift of Dr. Elkin.

## ADDITIONS TO LIBRARY.

The contributions to the Library of the Observatory during the year ending with May 31st, 1899, have been as follows:

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| —— —— —— 1882. *Adelaide*, 1885. | —— |
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| —— —— —— 1888. *Adelaide*, 1890. | —— |
| —— —— —— 1889. *Adelaide*, 1891. | —— |
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| —— | —— —— Nachgelassene Beobachtungen veränderlicher Sterne. F. W. A. Argelander. 4°. *Bonn*, 1898. |
| —— | Bordeaux. L'Observatoire. Annales. Par G. Rayet, Directeur. 4°. Tome VIII. *Paris* and *Bordeaux*, 1898. |
| The Academy. | Boston. American Academy of Arts and Sciences. Proceedings. Vol. XXXIII, Nos. 18–27. 8°. *Boston*, 1898. |
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| The Institute. | Bucharest. Institutul Meteorologic. Buletinul Observatiunilor Meteorologice din România. Steffan C. Hepites, Directorul. 4°. Anul. VI, 1897. *Bucuresci*, 1898. |
| —— | —— —— Analele. Tomul XII, Anul 1896. 4°. *Bucuresci*, 1898. |
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| —— —— —— Fasc. 8. Posizioni de 21 Stelle fra la $5^a$ e $7^a$ Grandezza. *Firenze*, 1898. | —— |
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| —— —— Assumed Mean Right Ascensions of Clock Stars with the corrections to the R. A. of the Nautical Almanac for 1899 o. 4°. *London*, 1898. | The Lords Commissioners of the Admiralty. |
| —— —— Nautical Almanac and Astronomical Ephemeris for the year 1902. 8°. *London*, 1899. | —— |
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| —— —— —— $2^{\text{ème}}$ Partie. *Haarlem*, 1898. | —— |
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| —— Acta Societatis Scientiarum Fennicae. Tom. XXII. 4°. *Helsingfors*, 1897. | —— |
| —— —— Tom. XXIII. *Helsingfors*, 1897. | —— |
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| —— | —— —— —— No. VIII. [Latitude variations, 1892–1893.] M. A. Gratschew. *Kasan*, 1897. |
| —— | —— —— —— No. IX. [Geodetic determinations.] A. B. Krasnow. *Kasan*, 1898. |
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| Dr. Wm. L. Elkin. | —— —— —— Vols. 50 and 51. *London*. NOTE.—With the Volumes received from Professor Loomis' bequest, our set of this serial is now complete, |
| Dr. Wm. L. Elkin and R. Brown. | —— —— Monthly Notices. 8°. [Vols. XIX–XXVI, included, as above, in Memoirs Vols. XXVIII–XXXV.] Vols. XXVII (lacking No. 7), XLIX, No. 9, L–LII. *London*, [v. d.] |
| Dr. Wm. L. Elkin. | —— —— —— Vols. LIII–LVIII. *London*, 1892–1898. |
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[NOTE.—With the Volumes received from Professor Loomis' bequest, our set of this serial lacks Vol. III, Nos. 1–12, Vol. IV, Vol. V, Nos. 1–6 and 20–24 and Vol. XXVII, No. 7.]

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| —— Royal Society. [Phil. Trans. Series A. Vol. 191, pp. 441–499. 4°.] Experiments on Aneroid Barometers at Kew Observatory, and their Discussion. C. Chree. *London*, 1898. | Kew Observatory. |
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| —— K. Sv. Vet-Akad. Förhandl. No. 7–9, 1898. Meddelanden från Lunds Astronomiska Observatorium. 8°. | The Observatory. |
| 1. Ueber Kometenbahnexcentricitäten. I. Elis Strömgren. *Stockholm*, 1898. | —— |
| 2. Eine Metode den Jupitersradius zu bestimmen. C. A. Schultz-Steinheil. *Stockholm*, 1898. | —— |
| 3. Ueber akromatische Linsensysteme aus einer Glassorte. C. V. L. Charlier. *Stockholm*, 1899. | —— |
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| —— | —— R. Istituto Lombardo di Scienze e Lettere. Memorie. Vol. XVIII, Fasc. V. Origine del Sistema Planetario Eliocentrico presso i Greci. Giovanni Schiaparelli. 4°. *Milano*, 1898. |
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" Astronomische Nachrichten"; "The Astronomical Journal"; " Vierteljahrsschrift der Astronomischen Gesellschaft"; " Science" and " Nature."

THE THERMOMETRIC BUREAU.

The work in this department, under the charge of Mr. Peck, has continued about the same as during the preceding year.

Very respectfully submitted,

ROBERT BROWN,

*Secretary of the Observatory.*

REPORTS FOR THE YEARS 1900 to 1904, PRESENTED BY THE BOARD OF MANAGERS OF THE OBSERVATORY OF YALE UNIVERSITY TO THE PRESIDENT AND FELLOWS.

# Observatory of Yale University.

## BOARD OF MANAGERS.



## OFFICERS.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The Board of Managers herewith transmit the Reports of Dr. Elkin, Director, for the past six years.

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1904-1905.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The results of the revision of my measurement of the Pleiades, made in 1884-1886 with the Yale Heliometer, and the second Yale Triangulation of the Pleiades, carried out by Mr. M. F. Smith in 1901-1903, have been printed and distributed as Parts VII and VIII of, and completing, Vol. I of our Transactions.

The observational work with the Heliometer has been somewhat restricted this past year, partly in order to push forward the reductions of the parallax investigations on large proper motion stars and partly to afford Dr. Chase a well-earned rest. Dr. Chase was absent on leave last summer, but since his return has taken up a series on 61 Cygni. Mr. Smith has continued the research on the parallax of the Pleiades and begun another on 1830 Groombridge.

The final results for all the stars of this parallax work except four, for which it seems desirable to secure a few more observations in the present season, have been derived.

The meteor-photography apparatus was put in use at the past November epoch and one Leonid trail recorded. I am now engaged on a discussion of all available photographic records of Perseids and Leonids.

Messrs. Chase and Smith have had the time service in charge and Miss Palmer and Miss Newton have been employed in computing work, as in former years.

W. L. ELKIN.

## 1905-1906.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The work on the parallaxes of stars of large proper motion and a few others, one hundred and sixty-three in all, which was outlined in my report for 1892 and which has absorbed a large part of the energy of the Observatory since then, has now been finally brought to a close; the results have been reduced and discussed, the complete manuscript is in the hands of the printer and should be issued at an early date.

The Heliometer has been again put into active operation: Dr. Chase is carrying out two series for parallax on 61 Cygni and a further one on Arcturus. Mr. Smith has completed the series on the parallax of the Pleiades, continued the one on 1830 Groombridge and begun others on $\alpha$ Geminorum, $\gamma$ Leonis and $\sigma$ Draconis besides an additional one on Arcturus.

The meteor-apparatus was utilized during the August period and six trails photographed on August 3, four of them Perseids; and again at the predicted date for the Andromedids, November 18, when although the visual shower was very slight, three meteors from this radiant were recorded. Unfortunately, however, none of them was timed or seen.

The time service has been carried on as usual by Messrs. Chase and Smith and Miss Palmer and Miss Newton have been engaged in computing work, as formerly.

W. L. ELKIN.

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## 1906-1907.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The printing of Part I of our Vol. II, containing the results of the parallax researches on 163 stars, carried out from 1892 to 1906, was completed and the work distributed last fall.

The Heliometer is now being devoted in this same field of stellar parallax to the following subjects:

A. Those stars of very large proper-motion which thus present particular interest and importance and which have not as yet been investigated with the Yale Heliometer. Of these, in addition to Arcturus, for which Dr. Chase and Mr. Smith have each secured a further series, 61 Cygni has been taken up in a very complete manner by Dr. Chase with four distinct series, and 1830 Groombridge and Sigma Draconis by Mr. Smith.

B. Those second magnitude stars which as yet have not been subjected to scrutiny by reliable methods; of these Mr. Smith has completed a double series on Alpha Geminorum.

C. Those stars of larger proper-motion for which the Yale survey showed either a large positive or negative value.

Mainly on account of the unfavorable moonlight conditions no photographic work on meteors was attempted this past season.

As in former years, the time service has been maintained by Dr. Chase and Mr. Smith, and Misses Palmer and Newton engaged in computing work and on the Durchmusterung Index.

W. L. Elkin.

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1907-1908.

*To the President and Fellows of Yale University:*

Gentlemen:—In pursuance of the programme outlined in the Observatory report for 1907, there have been carried out with the Heliometer for their parallax:

A. On stars with very large proper-motion, series on 34 Groombridge, Lalande 21185 and Arcturus by Dr. Chase and on 1830 Groombridge by Mr. Smith.

B. On second magnitude stars, series on Gamma Andromedæ and Gamma Orionis by Dr. Chase and on Gamma Leonis, Zeta Ursæ Majoris and Alpha Ophiuchi by Mr. Smith.

C. On stars of our former work showing extreme values, series on Weisse $17^{h}$ 322 by Dr. Chase and on 5 Serpentis, Lalande 46650 and Weisse $20^{h}$ 1454, by Mr. Smith. Dr. Chase has also secured series on the comparison stars of that series on Weisse $17^{h}$ 322, which diverged widely from the others.

The photographic apparatus was put in use during the Perseid epoch but, mainly on account of the unfavorable weather, no meteor trails were secured.

Misses Palmer and Newton have been employed on the Durchmusterung Index and Miss Palmer has in addition taken up her former work on computations of definitive comet orbits and selected for this purpose the three comets discovered by Caroline Herschel in 1786, 1788 and 1797.

The time service has been carried on as usual by Dr. Chase and Mr. Smith, and the latter, since the retirement of Mr. Brown, has been engaged in the library.

W. L. Elkin.

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## 1908-1909.

*To the President and Fellows of Yale University:*

Gentlemen:—The Heliometer work has been carried forward on the lines of the plan begun two years ago. Dr. Chase has practically completed his series on the large proper-motion and second magnitude stars and also one on 33 Virginis, a star which gave an abnormal result in his previous work. Mr. Smith has also nearly finished the stars of those classes he had taken up and series on thirteen stars with proper motions approaching a half-second are near completion on a scale similar to that of our former parallax survey. An improvement of some importance has been made by adapting the clock of the photographic instrument to the Heliometer, doing away with a certain amount of tremor that the old clock was liable to produce. The mechanical work was done by Mr. Smith himself.

Photographic work on meteors was undertaken during the August period on six nights. Three trails were recorded

on the Observatory plates two of which were also on the Whitneyville plates, both being from the Perseid radiant and both furnishing values for velocity.

The time service continues to be in the hands of Messrs. Chase and Smith; Miss Palmer and Miss Newton have continued the work on the Durchmusterung Index and the former also on the comets chosen by her for definitive orbits.

W. L. ELKIN.

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## 1909-1910.

*To the President and Fellows of Yale University:*

GENTLEMEN:—The activity of the Observatory during the past year has been mainly directed to the completion of the programme outlined three years ago. This has been accomplished and the memoir on the parallaxes of 35 selected stars is now being passed through the press. In continuance of the parallax survey with the Heliometer Dr. Chase has begun series on stars south of the Equator. Mr. Smith is engaged on a revision of series which presented somewhat abnormal results. An intermediate fine motion in position angle has been adapted to the instrument by Mr. Smith.

The meteor apparatus was utilized during the Perseid epoch on four nights and five trails were recorded on the Observatory and four on the Whitneyville station plates. All of the material so far secured has been measured and reduced and I am now undertaking a complete revision of the whole work.

The time service has been maintained by Dr. Chase and Mr. Smith; Dr. Palmer has continued the work on the definitive comet orbits and with Miss Newton that on the Durchmusterung Index.

W. L. ELKIN.